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Analysis of the Spatial Distribution Characteristics and Influencing Factors of Traditional Mosque Architecture in the Hehuang Area (China)

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Abstract: Clarifying the spatiotemporal distribution and influencing factors of mosque architecture in China's Hehuang region has significant positive implications for the overall protection and development of the region's architectural cultural heritage. This study utilizes field surveys and acquires POI data of traditional mosques built before 1993 in the region to analyze the distribution characteristics of mosques, aiming to explore future development trends of these religious structures. It also investigates the influencing factors, with the goal of emphasizing the primary and secondary factors affecting mosque distribution. The study finds the following: (1) Mosques are generally centered around the Huangshui Valley, displaying a "central clustering, peripheral dispersal" distribution pattern, forming a spatial structure of "two cores, one belt, multiple points", with distinct differentiation and overall uneven distribution. (2) Mosques are primarily situated at elevations between 2147 and 2764 m; on slopes less than 15°, in sunny and gentle slopes; within 20 km from rivers; within 14 km from roads; in areas receiving 400–500 mm annual rainfall; and within temperature ranges of 5.54–10.22 °C. (3) The study also finds that the spatial distribution of mosques is profoundly influenced by both natural geographical factors and human environmental factors. The better the natural location, the larger and denser the population, the richer the cultural resources, the higher the level of economic development, and the greater the concentration of Hui people, the more numerous and concentrated the mosques. (4) Population factors are the dominant factors for the clustered distribution of traditional mosques in the Hehuang area. Since the construction of mosques in the region is closely related to the number of Hui people and the proportion of Muslim adherents, areas with a high concentration of mosques also have relatively larger populations of Hui people. Temperature, precipitation, altitude, rivers, and roads are foundational factors for traditional mosques in the Hehuang area, influencing mosque distribution as external factors.

Keywords: Hehuang area; traditional mosques; spatial distribution characteristics; influencing factors; buffer analysis; geographical detector; GIS

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Citation: Huang, Y.; Xue, Q. Analysis of the Spatial Distribution Characteristics and Influencing Factors of Traditional Mosque Architecture in the Hehuang Area (China). *Buildings* **2024**, *14*, 1258. https://doi.org/10.3390/buildings14051258

Academic Editor: Nikos A. Salingaros

Received: 14 March 2024
Revised: 25 April 2024
Accepted: 28 April 2024
Published: 29 April 2024

1. Introduction

Islam rapidly evolved from being the sole religious faith of the Arab region's people to becoming one of the three major religions worldwide, gradually gaining global recognition. In 610 AD, the decline and disintegration of the Himyarite Kingdom led to changes in the Arabian Peninsula, becoming a crucial factor in the economic, political, and religious cultural transformation of Arab dynasties. This shift heralded the emergence of a series of new religious leaders and movements, marking the establishment of Islam's own domain [1]. This catalyzed the emergence of a series of new religious leaders and movements, marking the domain of Islam [2,3]. Islam has a history of over 1300 years since its introduction to China during the Tang Dynasty. Muslim culture has not only left a millennium of cultural history in the sacred Hehuang area along the ancient Silk Road, but it also embodies the exchange and mutual appreciation of diverse cultures between China and other civilizations [4]. Religious buildings often carry strong religious beliefs and canonical concepts, making them closely related to religious activities and resulting in architecturally flexible and diverse spaces. Within the architectural system of the Hehuang, traditional mosque architecture is particularly prominent, with multiple courtyard units mixed with residential buildings to form "mosque-residential" integrated communities. Spatially, the communities formed by the mix of mosque courtyards and residential areas are a unique manifestation of mosque architecture in the region. Multiple traditional mosques collectively constitute the region's focal points, laying the foundation for the holistic development of traditional mosques within the area. Through spatial analysis, the distribution of traditional mosques is not only related to multiculturalism and historical development but also closely linked to the regional environment. Given that the Hehuang area is located in Northwest China with a complex geographical environment, diverse climate changes, and undulating terrain, with most residents concentrated in the Hehuang valley, natural factors significantly influence the spatial distribution of traditional mosques [5]. Location, topography, and transportation also subtly affect the distribution and development trajectory of mosques. Therefore, to further clarify the spatial distribution characteristics of traditional mosque architecture in the Hehuang area, and to elucidate the influences on traditional mosque architecture during its developmental and evolutionary processes, an exploratory analysis of traditional mosque architecture in the Hehuang area can not only enrich and complement the theories of religious geography but also positively contribute to the inheritance and protection of Chinese cultural heritage and development.

The mosques built before 1993 in the Hehuang area generally adopted traditional Chinese architectural forms. Since most early mosques were constructed using traditional Chinese wooden structures, combined with exquisite craftsmanship and the advancement of national policies, this quickly became the main driving force for mosque construction in the region. The typical mosque layout features a courtyard style, with the main hall in the center, auxiliary rooms on the sides, and a symmetrical and orderly arrangement along a central axis. The entry from the temple gate to the prayer hall progresses through different courtyard spaces, deepening layer by layer. Decorative elements include plants, flowers, and geometric patterns, with green or white as the main exterior colors, contrasting sharply with other religious buildings. The main prayer halls primarily use traditional Chinese wooden structures, forming multi-eaved, pavilion-style buildings with traditional decorations such as archways, screen walls, animal figures, and painted motifs. Additionally, these mosques also incorporate elements of Western Islamic influence, gradually developing a Sino-Western architectural style that stands out within the traditional Chinese architectural system, leading to their designation in this text as "traditional mosques". In previous research on mosques, the academic community has largely focused on areas such as the decorative styles, architectural structures, and construction systems of mosques [6–8]. The main discussions revolve around the architectural forms of mosques, including the decorative arts and construction techniques demonstrated during the building process. Mosques in the Hehuang area generally adopt traditional Chinese architectural forms, with their typical architectural features being unique within the Chinese traditional architectural system. Some scholars have started from the perspective of mosque murals to study the decorative arts of mosques, elucidating the aesthetic characteristics of Islamic architecture [9]. Chinese scholars, starting with individual traditional mosque buildings, such as Hangzhou's Phoenix Mosque [10], Xi'an's Huajue Lane Mosque, and A'cheng Mosque, among others, have explored their architectural historical evolution and cultural connotations [11]. Mosques are widely distributed and numerous globally, and scholars have examined their role in education and religious belief by analyzing the interplay between Islam and education [12]. Other scholars have focused on the spatial functionality of mosque architecture [13,14], its refuge capabilities [15,16], seismic resistance [17,18], dome lighting performance [19], and architectural energy efficiency [20]. Research on individual structures mainly focuses on architectural structural performance [21], column styles [22], and visual comfort [23]. Current research is predominantly concentrated in regions with a high Muslim population, such as Saudi Arabia [24], Iran [25], and Algeria [26], in Western Asia and North Africa. From a technical approach, scholars have addressed practical issues in metropolitan development through GIS methods, qualitative and quantitative techniques, as well as demographic and sociological factors. By employing spatial analysis, they have focused on the relationship between rural and urban areas, connectivity of transportation, geographic location, and more [27]. Currently, many scholars utilize Geographic Information Technology (GIT) to study the architectural forms, characteristics, and aesthetics of mosques, thereby highlighting the significance of GIT in the protection of cultural heritage. However, research on promoting the protection and development of mosque architecture through GIT is still scarce; thus, the current research focus should be on the role of technology in enhancing and protecting architectural cultural heritage. Therefore, it is not only important to emphasize the critical role of GIT in architectural cultural heritage but also to highlight its facilitative role in the protection and utilization of architectural cultural heritage, an aspect currently lacking in research. For this reason, this study employs GIT to research the distribution and status of mosques within a region, aiming to promote the overall protection and development of mosque architecture in the area. Overall, academic research on mosques has primarily focused on their architectural structures and functional roles, with less depth in discussions on the protection of architectural heritage within certain regions and regional sustainable development. Thus, discussing the spatial-temporal distribution characteristics and influencing factors of traditional mosques built in the Hehuang area before 1993 has a positive effect on architectural cultural inheritance, heritage protection, and regional sustainable development.

In short, although scholars around the world have conducted in-depth studies on mosque architecture, most have focused on the structural performance and the physical environment of mosques, starting from individual buildings, yet lacking a comprehensive analysis of mosques within broader regions and a profound macroscopic examination. Furthermore, there is a significant difference in architectural form between Western mosques and Chinese traditional mosques. The majority of Western research focuses on mosques with dome structures, whereas Chinese traditional mosques are composed of traditional wooden structures, making the study of traditional mosque architecture of particular historical value, reflecting the inheritance and development of historical culture. This article, integrating the aforementioned research and yet-to-be-explored issues, draws on experiences, capitalizes on strengths while avoiding weaknesses, and from a holistic perspective, grasps the development direction and distribution characteristics of traditional mosques, aiming to revitalize and inherit cultural heritage within the region, thus promoting concentrated and contiguous protection of traditional architecture. By analyzing the spatial distribution characteristics of traditional mosques built in the Hehuang area before 1993 and identifying their influencing factors, this study inductively discusses the distribution patterns of mosques in the Hehuang area, especially from the perspective of influencing factors, attempting to explore the formation and evolution process of traditional mosques in the Hehuang area and their influencing mechanisms, thereby providing empirical cases and reference experiences for the protection of historical religious geography and Islamic architectural cultural heritage.

2. Study Area

The Hehuang area is located in the transitional zone between the Qinghai-Tibet Plateau, the Loess Plateau, and the Inner Mongolia Plateau, encompassing Xining and Haidong cities of Qinghai Province, as well as Haibei, Huangnan, and Hainan Tibetan Autonomous Prefectures, and relevant counties in the southwestern part of Gansu Province. Geographically, it is located between 34°7′31″ N and 39°5′7″ N latitude and 98°6′49″ E and 104°38′28″ E longitude, covering an area of about 168,007.80 km^2 (Figure 1). It is a junction of the eastern monsoon area, the semi-arid region of the northwest inland, and the Qinghai-Tibet Plateau, making it a complex region where agricultural and pastoral areas interlace. In the

Hehuang area, the northwest, south, and west are relatively high in elevation, whereas the east and middle areas are lower, with altitudes ranging from 1565 to 5280 m. The terrain is a crisscross of river valleys, hills, gorges, mountains, and plateaus interspersed throughout the area. The region experiences a harsh climate, with low precipitation, high evaporation, and significant spatial differences. It has long sunshine hours, large daily temperature variations, small annual temperature differences, cool summers, and cold winters, with particularly noticeable temperature changes in winter [27,28]. Due to natural constraints, the Hehuang Valley has very limited space suitable for population distribution. The region has fewer grids of population distribution, mainly along the main and tributaries of rivers, concentrated in areas with smaller slopes and lower altitudes. Simultaneously, the geomorphological types of the Hehuang Valley are complex and varied, primarily consisting of erosive structural mountains, loess ridge-shaped hills, and erosive denudation residual mountains. The terrain is highly undulating, with slopes of varying degrees, divided into five types: flat land (≤3°), gentle slope land (3°–6°), slope land (6°–15°), steep slope land (15°–25°), and sharp steep slope land (>25°). Areas with ground slopes above 25° suffer from severe soil erosion and are unsuitable for farming. Although the Hehuang area has diverse slope orientations, the river valleys receive ample sunlight, with many areas facing the sun [29,30]. See Table 1 for a detailed overview of geographical areas.

Table 1. Overview of geographical regions.

Geographic Feature	Hehuang Area
Geographic position	34°7′31″ N−39°5′7″ N, 98°6′49″ E−104°38′28″ E
Surface area	168,007.80 km^2
Altitude	Northwest, southern, and western terrain is higher, the eastern and central terrain is lower, the highest altitude is 5280 m, the lowest altitude is 1565 m
Air temperature	The annual average temperature is −1 °C–15 °C
Slope	Most are between 3° and 15°
Historical relics	Painted pottery, temples, Kayue culture, multi-ethnic mixed residence

The Hehuang area is a multi-ethnic area where Han, Hui, Tibetan, Salar, and Tu ethnic groups have thrived for generations, making the Hehuang civilization an integral part of Chinese civilization. Historically, the Hehuang area has been an important transportation route on the Qinghai South Road, the Tang-Fan Ancient Road, and the ancient Silk Road, serving as a typical ethnic corridor with significant research value [31]. The Hehuang area is also an area with diverse religious beliefs, featuring a variety of sects and numerous temples. Tibetan Buddhism and Islam, in particular, have a significant following in this region and exert a profound influence. Islam primarily spreads among ethnic groups such as the Hui and Salar, predominantly in the river valley agricultural areas of eastern Qinghai, the city of Xining in western Qinghai, and other agricultural areas and towns. To this day, Islam remains a vital spiritual pillar and religious belief for the Hui, Salar, and other ethnic groups. Throughout its long historical development and evolution, Islam has continuously interacted extensively and closely with other ethnic groups, integrating elements of Han, Mongol, and Tibetan cultures, thereby forming an inseparable relationship with these ethnicities [32].

Over time, the Hehuang area has gained recognition from various academic fields, gradually drawing attention from disciplines such as ethnology, anthropology, religious studies, geography, and archaeology [33,34]. The article integrates archaeology and human geography to analyze and explore the spatial differentiation characteristics and driving factors of traditional mosques in the Hehuang area, aiming to promote the preservation of architectural culture and the integration of multi-ethnic exchanges.

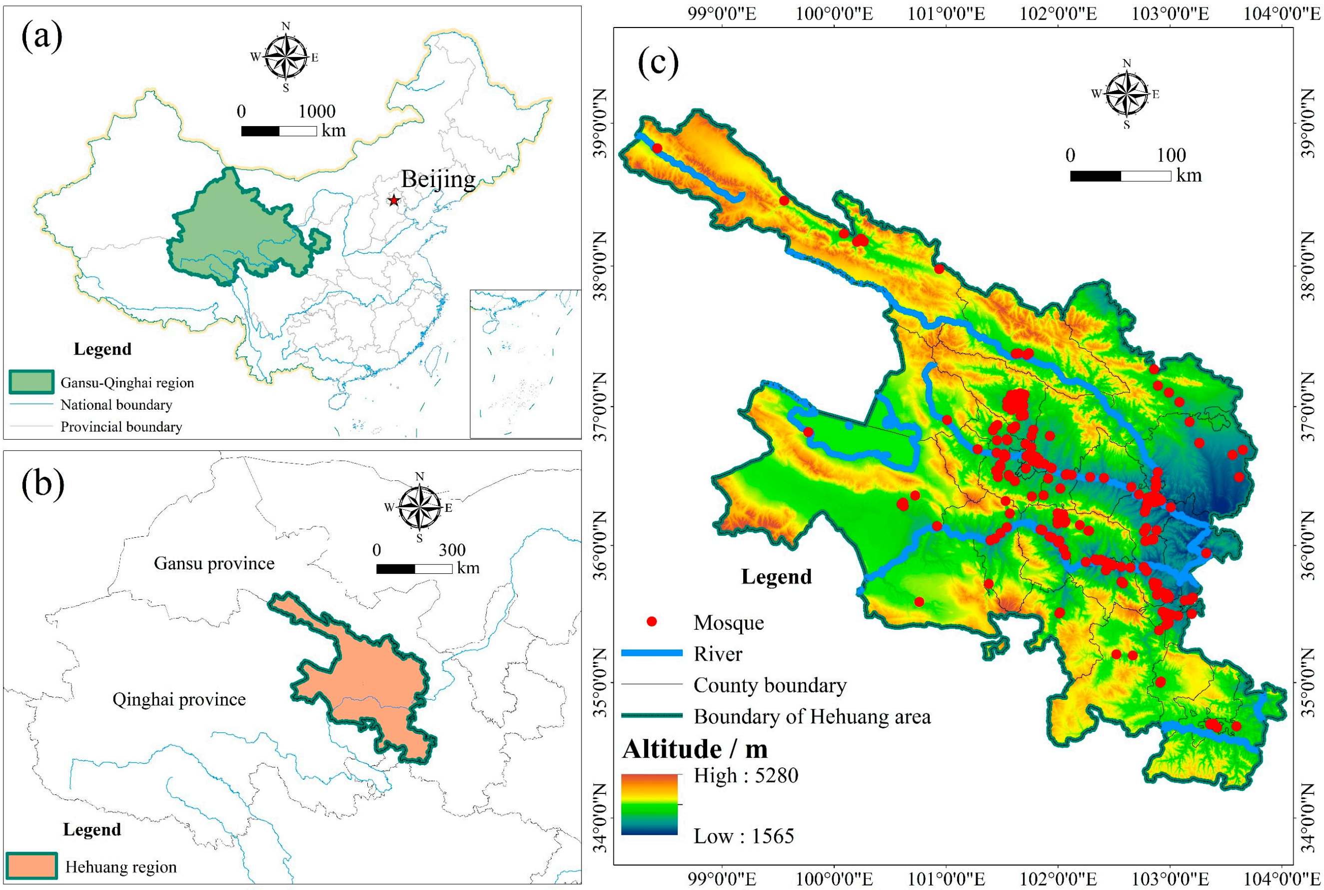


Figure 1. Study section range. ((**a**). The location of the Gansu-Qinghai region in China; (**b**). The location of Hehuang area in Gansu-Qinghai; (**c**). An overview of Hehuang area). Note: Figures (**a**–**c**) are based on the standard maps of GS (2020) 4615, Qing S (2021) No.257 and Gan S (2021) No.91, Qing S (2021) No.258 and Gan S (2021) No.91 downloaded from the national standard map service website and the website of Gansu Provincial Department of Natural Resources, the base map was made without modification.

3. Materials and Methods

3.1. Data Sources

To simplify and clarify the paper, making it more direct and intuitive, abbreviations used in the article are listed in Table 2. According to historical documents such as "Islam in Qinghai", "Qinghai Provincial Ethnic Chronicles", "Xining Guard Chronicles", and "Qinghai Provincial Chronicles-Religious Chronicles", the traditional mosques in the Hehuang area were built between 1368 and 1993, with a significant number constructed during 1888–1980. A few mosques were built between 1628 and 1700, with some of the latest constructions occurring in 1992. Over time and with development, some mosques have been demolished. Presently (before 2023), the traditional mosques in the Hehuang area largely coincide with those existing before 1993. To obtain more precise data on mosque locations, traditional mosque Point-of-Interest (POI) data in the Hehuang area were captured using the Amap (Gaode Map) Application Programming Interface (API) and then displayed on the map using the Geographic Information System (GIS). To further ensure the accuracy of the number and locations of mosques, field surveys were combined with historical document comparisons. This process ultimately identified a total of 270 mosques in the Hehuang area before 1993 (Figure 1c). Additionally, geographic information data include latitude and longitude information from Google Earth and the Baidu Coordinate System. Spatial vector data were created using standard map basemaps downloaded from the Ministry of Natural Resources standard map service website, with no modifications to the basemaps (http://bzdt.ch.mnr.gov.cn, accessed on 22 December 2023). Digital Elevation Model (DEM) digital elevation data were sourced from the Geospatial Data Cloud platform of the Chinese Academy of Sciences (https://www.gscloud.cn, accessed on 22 December 2023). Road traffic data were obtained from the Open Street Map (OSP) (https://www.openstreetmap.org, accessed on 22 December 2023) open-source platform, and river data were sourced from the 1:250,000 National Basic Geographic Database provided by the National Geographic Information Resources Catalog Service System (https://mulu.tianditu.gov.cn, accessed on 25 December 2023). The 2022 China 1 km resolution precipitation data and annual average temperature data were sourced from the National Earth System Science Data Center (http://www.geodata.cn, accessed on 22 December 2023). The data from the seventh population census in 2020 were obtained from the World City Population website (http://www.citypopulation.de, accessed on 20 December 2023), and other data such as the 2022 GDP, 2020 population density, etc., were obtained from the China Statistical Yearbook. Specific spatial data sources are shown in Table 3.

Table 2. Abbreviations statistics.

Full Name	Abbreviations
Geographic Information Technology	GIT
Point of Interest	POI
Application Programming Interface	API
Geographic Information System	GIS
Digital Elevation Model	DEM
Open Street Map	OSP
Gross Domestic Product	GDP
Standard Deviation Ellipse	SDE
Nearest Neighbor Index	NNI
Kernel Density Estimation	KDE

Table 3. Spatial data classification and source.

Data Classification	Data Sources
Spatial vector data	http://bzdt.ch.mnr.gov.cn, accessed on 22 December 2023
DEM digital elevation data	https://www.gscloud.cn, accessed on 22 December 2023
Road traffic data	https://www.openstreetmap.org, accessed on 22 December 2023
River data	https://mulu.tianditu.gov.cn, accessed on 25 December 2023
2022 China 1 km resolution precipitation data and annual average temperature data	http://www.geodata.cn, accessed on 22 December 2023
Seventh population census	http://www.citypopulation.de, accessed on 21 December 2023
2022 GDP, 2020 population density	China Statistical Yearbook, accessed on 20 December 2023

3.2. Research Method

This paper employs six methods to analyze the distribution of mosques in the Hehuang area: Global Moran's I, SDE, NNI, KDE, buffer analysis, and geographical detector. Firstly, Global Moran's I is primarily used to indicate the agglomeration of mosques in the Hehuang area. SDE is mainly used to observe the distribution trends and characteristics of mosques in the Hehuang area. NNI primarily represents the overall distribution pattern of mosques in the Hehuang area, calculating the average nearest-neighbor distance. KDE is mainly used to monitor the density of mosques in the Hehuang area, identifying areas of high and low-density clustering. Buffer analysis is primarily used to examine the relationship between mosques and other influencing factors. Geographical detector is mainly used to elucidate the interactions between various factors and to identify the primary and secondary factors influencing mosques. These six methods are interrelated and complementary. The specific process is shown in Figure 2.

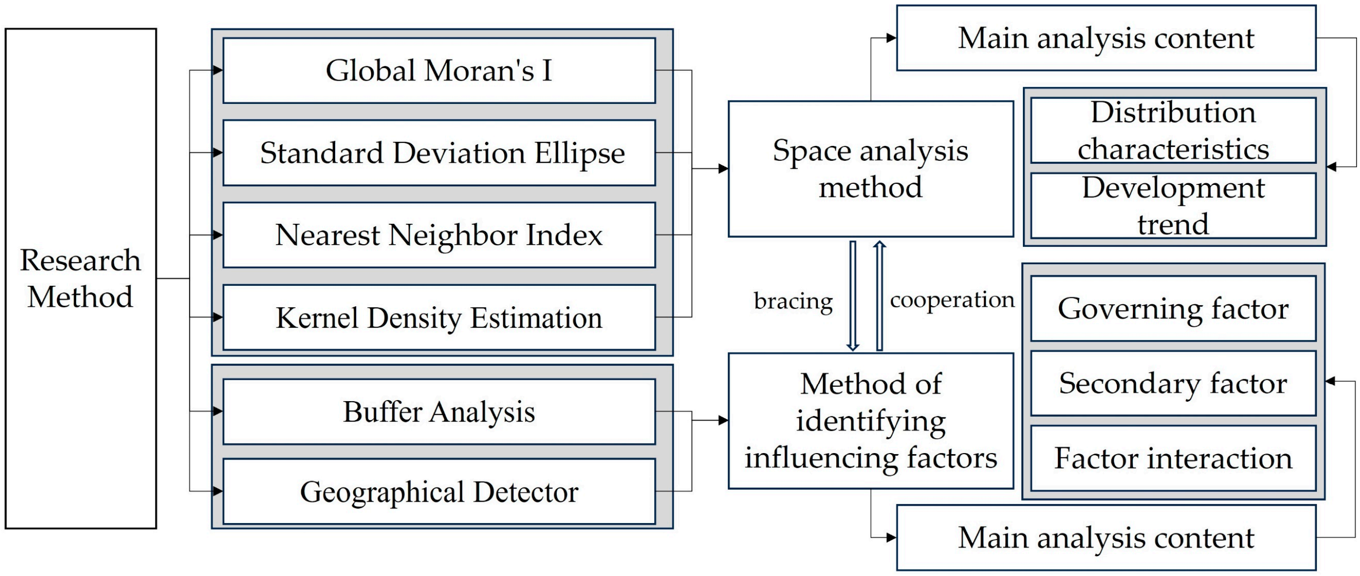


Figure 2. Research method flow chart.

3.2.1. Global Moran's I

Given the numerous administrative boundaries within the Hehuang area and the scattered distribution of traditional mosques, this paper aims to more precisely examine whether these mosques exhibit characteristics of spatial clustering and differentiation. This study explores the clustering of mosque spatial distribution from both global and local autocorrelation perspectives, with the goal of better observing the spatial clustering of mosques within the region. Global Moran's I is used to verify the clustering tendency of mosques across the entire regional space, and the calculation formula is as follows [35]:

$$\text{Moran}'\text{s } I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}} \times \frac{\sum_{i=1j}^{n}\sum_{j=1}^{n} W_{ij}(x_i - \overline{x})(x_j - \overline{x})}{\sum_{i=1}^{n}(x_i - \overline{x})^2} \tag{1}$$

In Equation (1), n is the number of observations for the study object; x_i and x_j are the observation values; w_{ij} is the spatial weight connection matrix between object i and object j. "Moran′s I" values range from −1 to 1. A value greater than 0 indicates positive spatial autocorrelation, suggesting a clustered state; a value less than 0 indicates a dispersed state; and a value close to 0 indicates a random distribution. Local Moran's I is used to measure the degree of spatial difference between an attribute value of a study unit and the attribute values of its neighboring areas, with the calculation formula as follows:

$$\text{Local Moran}'\text{s } I = z_i \sum_{j=1}^{n} W_{ij} z_j \tag{2}$$

In Equation (2), z_i and z_j are the standardized values of the observations. The calculation results of "Local Moran′s I" are primarily divided into four types: "high-high", "high-low", "low-low", and "low-high", representing high-high clustering, high-low clustering, low-low clustering, and low-high clustering, respectively.

3.2.2. Standard Deviation Ellipse

Utilizing the Standard Deviation Ellipse (SDE) method allows for a clear observation of the distribution characteristics and orientations of mosques in the Hehuang area, thereby more effectively portraying the geographical locations of mosques. Based on the geographical and environmental background of the Hehuang area, the Standard Deviation Ellipse is employed to represent the center and centroid of mosques within the regional geometry. The spatial distribution orientation analysis of mosques is primarily conducted using ArcGIS, involving multiple frequency loading to calculate the azimuth angle (θ) in the formula for standard deviation values, representing the spatial distribution orientations of mosques. The major axis of the ellipse represents the degree to which mosques deviate from the centroid in the primary direction, and the minor axis represents the degree of deviation from the centroid in the secondary direction [36]. The calculation formula is as follows:

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

$$\sigma_x = \sqrt{2}\sqrt{\frac{\sum_{i=1}^{n}\left(\tilde{\chi}_i \cos\theta - \tilde{y}_i \sin\theta\right)^2}{n}}; \sigma_y = \sqrt{2}\sqrt{\frac{\left(\sum_{i=1}^{n} \tilde{x}_i \cos\theta - \tilde{y}_i \sin\theta\right)^2}{n}} \quad (3)$$

In Equation (3), $\tilde{x}_i$ and $\tilde{y}_i$ represent the coordinate deviation values from the geometric center to the centroid of the region, and σ_x and σ_y represent the standard deviations of the ellipse along the x and y axes, respectively.

3.2.3. Nearest Neighbor Index

The Nearest Neighbor Index (NNI) is commonly used to represent the spatial distribution of two attributes, depicting whether the spatial distribution of point features is clustered, random, or uniform. The principle of the NNI is to calculate the Euclidean distance between each point feature and its nearest neighbor in geographical space, determining the average nearest neighbor distance for point features in this space [37]. The ratio of the actual to the theoretical nearest neighbor distance is the NNI. This study primarily utilizes the NNI to investigate the overall distribution of traditional mosques in the Hehuang area, indicating the degree of proximity among mosques in urban development. It calculates the average nearest neighbor distance between them, comparing it to the distance expected by urban development. This allows for the determination of the mosques' locations and distribution characteristics within urban spaces, observing their degree of proximity within the region. The calculation formula is as follows:

$$R = \frac{\overline{r_i}}{\overline{r_e}} = \frac{\overline{r_i}}{2\sqrt{\frac{n}{A}}} \quad (4)$$

In Equation (4), $\overline{r_e}$ represents the average nearest neighbor distance of mosques in an ideal random spatial distribution; $\overline{r_i}$ represents the actual average nearest neighbor distance of mosques; A is the area size of the study region; n is the number of mosques distributed within the region. When $R = 1$, mosques are randomly distributed within the region; when $R < 1$, mosques are clustered within the region; when $R > 1$, mosques are evenly distributed within the region.

3.2.4. Kernel Density Estimation

The Kernel Density Estimation (KDE) method effectively represents the differentiation characteristics of point features within a regional space [38,39]. Thus, employing the KDE method to reflect the spatial distribution density of traditional mosques in the Hehuang area enables the identification of the variance in distribution levels, the disparity among these levels, and the degree of polarization. This subsequently facilitates the determination of concentrated areas of mosques within the region. The calculation formula is as follows:

$$f(x) = \sum_{i=1}^{n}\left[1 - \frac{(x - x_i)^2 + (y - y_i)^2}{h^2}\right]^2 / \left(\pi n h^2\right) \quad (5)$$

In Equation (5), x represents the actual points of mosques; h is the search radius within the region; n is the number of mosque points within the search radius. Each (x_i, y_i) point continuously spreads outward from the highest point in space, and the density value becomes zero when the distance from the center reaches the search radius (h) to a certain extent. When the kernel density value $f(x)$ is higher, it implies a greater distribution density of mosques; conversely, a lower kernel density value $f(x)$ indicates a lesser distribution density of mosques.

3.2.5. Buffer Analysis

Buffer analysis primarily examines the spatial characteristics of point, line, and polygon features within a specified buffer radius. It extends a set of features based on defined distance criteria to determine their spatial extents. This study primarily employs buffer analysis tools to conduct buffer analyses on roads and rivers. It abstracts road traffic and river systems as linear features and establishes polygons of a certain width outward from them. Overlay analysis is performed between mosque point features and the generated road and river buffers to obtain the number of mosques within different buffer radius ranges [40]. This approach aims to investigate their distribution patterns, discern the layout characteristics within the buffer radius of roads and rivers, and understand the relationship between mosques and roads/rivers. For the buffer size of a specific point A, the calculation formula is as follows:

$$P = \{x || d(x, A) \leq r\} \tag{6}$$

In Equation (6), r represents the radius of the buffer zone; d is the Euclidean distance from the planar point x to A; P denotes the buffer zone of feature A.

3.2.6. Geographical Detector

The geographical detector is a method to explore the spatial differentiation characteristics of geographical elements and reveal the reasons for spatial differentiation [41–43]. It includes four aspects, including factor detection, interaction detection, risk detection, and ecological detection, and is widely used in ecology, society, economics, and other fields. Its detector model can discern the relationship between influencing factors and geographical space without any linear assumptions, and its calculation process and results are not affected by multicollinearity. This study applies the geographical detector model to explain the spatial distribution of traditional mosques in the Hehuang area. By judging the magnitude of its q value, it detects the spatial correlation between mosques and influencing factors. The factor detection analysis method in the geographical detector is adopted in this paper to analyze the strength of each factor's impact on the spatial differentiation of mosques. The calculation formula is as follows:

$$q = 1 - \frac{\sum\limits_{h=1}^{L} N_h \sigma_h^2}{N\sigma^2} \tag{7}$$

In Equation (7), the q value measures the detection power of the independent variable, ranging from [0, 1]. The closer its value is to 1, the greater the influence and stronger the effect of the factor on the spatial distribution of mosques; L represents the stratification of the independent or dependent variable; N_h and σ_h^2, respectively, denote the number of units and the variance in layer h; N and σ^2, respectively, represent the total number of units and the variance of the whole.

The paper selects 11 main driving factors including the soil type, population size, population density, level of socioeconomic development, precipitation, temperature, slope, elevation, aspect, rivers, and roads as the research objects.

4. Results and Analysis

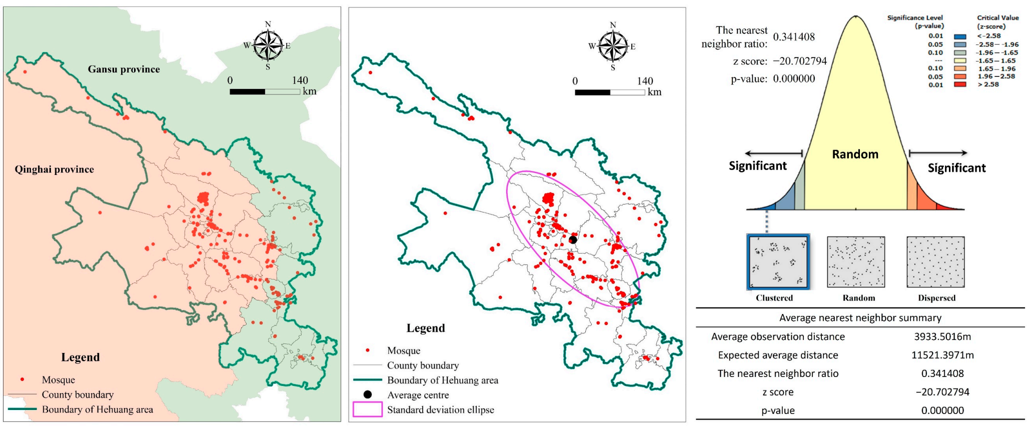
4.1. Spatial Distribution Characteristics

4.1.1. Spatial Distribution Quantitative Characteristics

As shown in Figure 3a, mosques are widely distributed in the Hehuang area, but there are varying degrees of differences in their number. Before 1993, there were a total of 270 traditional mosques in the Hehuang area. The distribution of these mosques was spatially uneven, generally centered around the Huangshui Valley, exhibiting a spatial distribution pattern of "central aggregation and peripheral dispersion." The Hehuang area comprises two provinces, Gansu and Qinghai. As clearly visible in Figure 3a, Qinghai Province (the yellow section) has a greater and more concentrated distribution of mosques, mainly in Xining, Haidong, and other areas, totaling 204 mosques, accounting for 75.56% of the total number of traditional mosques in the Hehuang area. Gansu Province (the green section) has fewer mosques, mainly concentrated in Linxia Hui Autonomous Prefecture, with a total of 66 mosques, accounting for 24.44% of the total. Xining, the capital city of Qinghai Province and an important city on the ancient Silk Road, with its diverse ethnic groups and significant Hui population, has laid a solid foundation for the construction of mosques. The surrounding cities, influenced by the capital, are increasingly converging towards Xining in terms of population and architecture, leading to a higher concentration of mosques near the provincial capital.

4.1.2. Spatial Distribution Type Characteristics

According to the Average Nearest Neighbor Summary Report (Figure 3c), the average nearest neighbor ratio for traditional mosques in the Hehuang area is 0.3414, and it passes the significance test at the 0.01 level, greater than the reference value of 1. The Z-score is −20.70, less than the reference value of 0, and the p-value is 0, less than the reference value of 0.01. This indicates a 99% confidence level, suggesting that the spatial distribution of traditional mosques built before 1993 in the Hehuang area is significantly clustered. The Standard Deviational Ellipse analysis (Figure 3b) shows that the mean center is located in Xining, Qinghai Province, indicating a more pronounced clustering of mosques in the Hehuang Valley. The distribution trend of mosques in the Hehuang area is in a "northwest-southeast" direction at 45 degrees, with mosques concentrated along this direction. The flatness ratio of 0.58 indicates a strong directional and trend-based spatial distribution of mosques, aligned with the direction of the Hehuang area. The clustering characteristic of mosques is evident at the center of the ellipse, with an average observed distance of 3933.50 m and a predicted average distance of 11,521.40 m. The observed value being less than the expected value indicates a high degree of mosque distribution clustering. In summary, the spatial distribution of mosques in the Hehuang area overall exhibits a characteristic of "major clustering with minor dispersion".



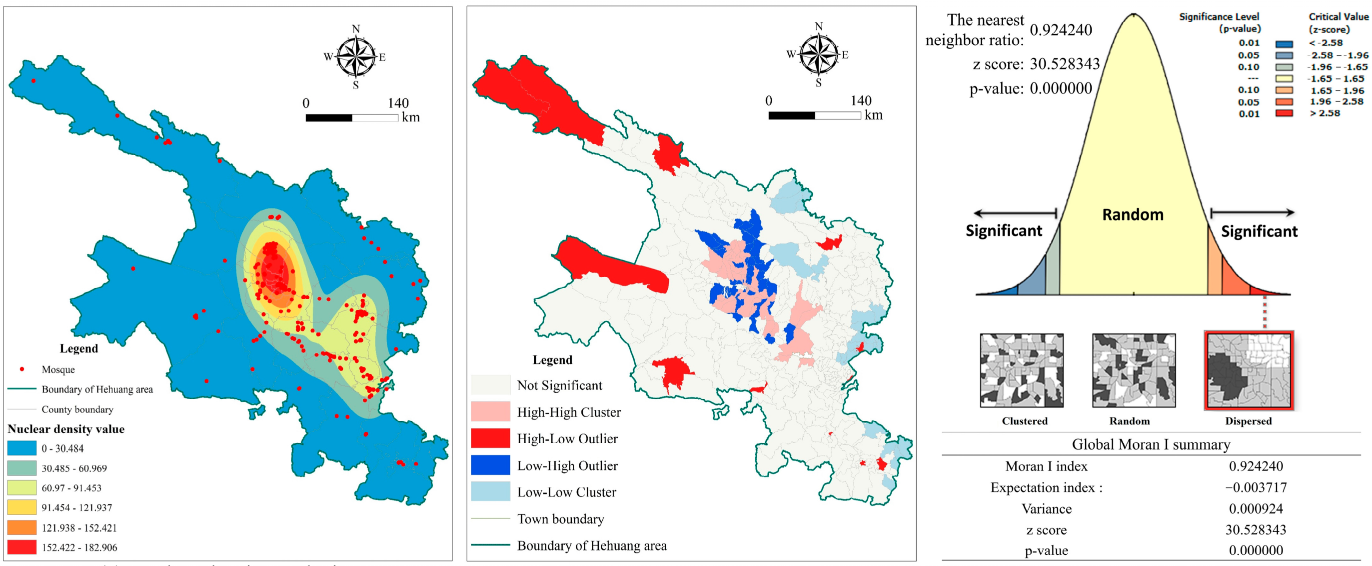
(a) Number of spatial distribution of mosques (b) Mosque standard deviation ellipse (c) Mosque nearest neighbor index

Figure 3. Analysis of spatial distribution quantity and type.

4.1.3. Spatial Distribution Density Characteristics

Utilizing GIS to perform kernel density analysis on traditional mosques built before 1993 in the Hehuang area, the results (Figure 4a) reveal two distinct clustering areas: one primarily around Xining-Huangzhong-Hualong-Xunhua-Huzhu; and the other around Linxia Hui Autonomous Prefecture. These two high kernel density areas are mainly concentrated in the Hehuang Valley, showing significant spatial distribution differences. Mosques in the Hehuang area exhibit higher densities in the central and southeastern parts, whereas the northwest and southwest parts have lower densities. The distribution trend decreases from southeast to northwest, with the highest density in the central area and sparser density in the northwest. The clustered areas are located in river valleys and hill regions, whereas the sparser areas are in mountainous and plateau regions. The Hehuang Valley, close to the Yellow River, with a developed water system and gentle terrain, provides a good foundation for agricultural development, reaching a peak kernel density of 182.90 per km^2. The low-density areas are located in regions like Gonghe, Qilian, and Zhuoni, near higher altitude areas like the Qilian Mountains and Gannan Plateau. This region is characterized by significant terrain undulations, sparse population, and frequent natural disasters and is prone to landslides and debris flows [44,45], with a low-density value of 30.48 per km^2.

From the global autocorrelation analysis (Figure 4c), the global Moran's I is 0.9242, indicating that the spatial distribution of traditional mosques in the Hehuang area is significant at the 0.01 level. There is a positive spatial autocorrelation within the region, tending towards a clustering trend, and this clustering is particularly evident within counties. The expected Moran's I is less than 0, but the Z-score is 30.5283, obviously greater than 0, indicating an overall tendency for mosques to cluster in the Hehuang area. From the local Moran's I (Figure 4b), the central Huangshui Valley shows high-high clustering, with low-high clustering around areas of high-high clustering. Farther from the central area, the western region exhibits high-low clustering, primarily in Qilian, Guinan, and Gonghe counties. The eastern region shows low-low clustering, close to Gansu Province, primarily in Yongjing, Zhuoni, and Lintan counties. From the local autocorrelation, it is evident that mosques in the Hehuang area overall display a spatial distribution characteristic of "high-high clustering in the middle, low-low clustering around the periphery." Although the traditional mosques in the Hehuang area show clear differentiation characteristics and overall uneven distribution, the clustering areas are distinct, and the overall spatial effect is significant, centered around the Huangshui Valley and extending outwards.



(a) Nuclear density analysis (b) Local autocorrelation analysis (c) Global autocorrelation analysis

Figure 4. Spatial distribution density analysis.

4.2. Influencing Factors of Spatial Distribution

4.2.1. Natural Environmental Factors

(1) Altitude Elevation Factors

Natural geographical factors are the basis for the distribution and formation of mosques. Elevation and topographical variations influence the distribution of traditional mosques in the Hehuang area through geographical location and natural climate. Utilizing 30 m resolution DEM data from the Hehuang area and employing ArcGIS 10.8 to extract elevation data, we reclassified and graded the data based on the terrain features of our study subjects. Using the natural break method, we divided the study area into six elevation levels. By overlaying, merging, and integrating analyses in ArcGIS, we spatially connected mosques with elevation data to explore the number of mosques in different elevation intervals and their spatial distribution characteristics at various altitudes, thus analyzing the relationship between the distribution of traditional mosques in the Hehuang area and elevation. Geographically, the Hehuang area is located in the northeastern part of the Tibetan Plateau, spanning the Qilian Mountains and connected to the western part of the Qinling Mountain Range. The Huangshui Valley belongs to the crystalline rock axis of the Qilian Mountains and is part of the "Central Qilian Plate." This region, a segment of the larger Western Regions Plate, with its complex geological structure and unique regional environment, has nurtured the people and culture of Hehuang. Its prolonged climate fluctuations, convergence of main and tributary streams, and the historical evolution of its ecological environment have garnered attention from the fields of geography and archaeology. In terms of elevation and topographical undulations (Figure 5a), the central area is low, whereas the surrounding areas are high, with elevations ranging from 1565 to 5280 m and an average elevation between 1500 and 2400 m. The complex terrain and landscape, characterized by interwoven mountains and rivers, form a plateau valley composed of high mountains, canyons, and basins. Mosques are primarily concentrated at elevations between 2147 and 2764 m, with 139 mosques accounting for 51.48% of the total number. Additionally, 72 mosques are located at elevations between 1565 and 2147 m, constituting 26.67% of the total (Figure 6). The remaining mosques are more dispersed in higher elevation areas, accounting for 21.85% of the total. It is evident that a larger number of mosques are located in relatively flat areas such as the Huangshui Valley, demonstrating a distribution pattern of "major clusters and minor dispersion" in space. Mosques in the Hehuang area are numerous and densely distributed. This region is dominated by river valleys and low hill landforms, with gentle terrain, making mosque construction less challenging. Several rivers converge in the valleys, creating a wide gathering area with a high density of mosques. Additionally, this area has advantageous conditions for crop growth and a solid foundation for agricultural development. In contrast, the surrounding high mountain areas have significant topographical variations, complex terrain, sparse population, limited cultivated land, harsh climatic conditions, and inconvenient transportation and are prone to natural disasters, making them less suitable for human habitation and construction. As a result, there are fewer mosques in these regions. Analyzing historical factors, the Hehuang Valley has long been a vital passageway and trade center on the ancient Silk Road, where most Muslim communities and Persian merchants conducted business and settled. Data indicate that before 1993, there was a negative correlation between the number of traditional mosques built in the Hehuang area and elevation. That is, the more mosques there were, the lower the elevation. These mosques were predominantly located in valley areas below 2800 m in elevation.

(2) Slope Aspect Factors

In analyzing the slope factor (Figure 5b), the Hehuang area exhibits a slope range from 0° to 79.95°, with an average slope of approximately 30° to 50°. Utilizing the ArcGIS platform, slope aspects were generated, and data were reclassified using the natural breakpoint classification method. Slope was categorized into six levels: 0°–5.96°, 5.96°–12.54°, 12.54°–19.13°, 19.13°–26.02°, 26.02°–34.17°, and 34.17°–79.95°. From Figure 6, it can be observed that mosques are most abundant in areas with slopes ranging from 0° to 5.96°, totaling 115 mosques, which constitute 42.59% of all mosques. Furthermore, there are 88 mosques situated in areas with slopes ranging from 5.96° to 12.54°, representing 32.59% of the total number of mosques. Based on the above analysis, it is evident that mosques in the river valley region are primarily situated in areas with slopes of less than 15°. Conversely, mosques in areas with slopes exceeding 15° are more sparsely distributed, and their numbers gradually decrease as slope steepness increases. This distribution pattern is influenced by topographical factors such as river valleys and mountainous terrain. Most mosques are concentrated in areas with relatively gentle slopes, suitable for human habitation, including gentle and moderate slopes. The data indicate that before 1993, the number of traditional mosques constructed in the Hehuang area was negatively correlated with slope. In other words, areas with a higher number of mosques had lower slopes. These mosques are predominantly located in areas with slopes less than 15°, specifically on gentle and inclined slopes.

In the analysis of slope aspects (Figure 5c), slope direction was generated using ArcGIS, resulting in ten directions, including flat, true north, northeast, northwest, true east, southeast, true south, southwest, and true west. The slope aspect data were reclassified and categorized into six levels using the natural breakpoint classification method: −1°–49.95°, 49.95°–115.06°, 115.06°–177.33°, 177.33°–236.78°, 236.78°–299.05°, and 299.05°–359.91°. As depicted in Figure 6, mosques are distributed across various slope directions. Notably, the number of mosques is relatively higher in slope directions ranging from 115.06°–177.33° and 177.33°–236.78°, with a total of 116 mosques, accounting for 42.96% of all mosques. Conversely, the number of mosques in the 49.95°–115.06° slope direction is relatively lower, with a total of 29 mosques, making up 10.74% of all mosques. Based on the aforementioned analysis, it is apparent that the traditional mosques built in the Hehuang area before 1993 were predominantly oriented towards the south and southwest. There were fewer mosques oriented towards the northwest and east. Influenced by factors such as the direction of sun-facing and shaded slopes, as well as religious beliefs, most mosques are located in areas facing north to south, abundant with sunlight.

(3) River Basin Factors

Using the buffer analysis tool in ArcGIS, buffer zone analysis was conducted on the major rivers in the Hehuang area. This analysis was combined with field surveys, river surface area measurements, and information on mosque distribution. The buffer zones were categorized into four regions: 1 km, 5 km, 10 km, and 20 km (Figure 5d). Spatial connections were established between each buffer zone and the mosques to investigate the coupling relationship between mosques and river distance. The results, as shown in Figure 6, indicate that within a distance of 20 km from the riverbanks, there are a total of 166 mosques. Beyond a distance of 20 km from the rivers, there are 104 mosques. Within a 1 km buffer zone from the riverbanks, there are 52 mosques, accounting for 19.26% of the total number of mosques. Within a 5 km buffer zone from the riverbanks, there are 58 mosques, constituting 21.48% of the total number of mosques. In the buffer zone 10 km away from the riverbanks, there are 13 mosques, making up 4.81% of the total. Within a 20 km buffer zone from the riverbanks, there are 43 mosques, representing 15.93% of the total. It is apparent that mosques in the Hehuang area are primarily concentrated within a 20 km distance from the rivers, indicating a coupling and correlation between river layout and mosque spatial distribution. The river valley region boasts a rich natural environment with diverse species and dense populations in gathering areas. Agriculture serves as the primary means of livelihood in this area, with a long history of agricultural practices. In the "Great Hehuang" region, the major river systems include the Yellow River, Huangshui River, and Datong River watersheds. These river systems flow from northwest to southeast through the Hehuang agricultural zone, providing a continuous source of water that has facilitated the local agricultural development. The watershed is characterized by abundant water resources, excellent water quality, and a broad watershed area. Areas near the water are densely populated, with frequent human activities. The Hui

Muslim population engages in farming and lives in the Huangshui River valley, where mosques are constructed in close proximity to rivers. Consequently, areas closer to the rivers exhibit a higher number of mosques. The data indicate that before 1993, the number of traditional mosques constructed in the Hehuang area is positively correlated with river proximity. In other words, areas closer to the rivers had a higher number of mosques, whereas areas farther from the rivers had fewer.

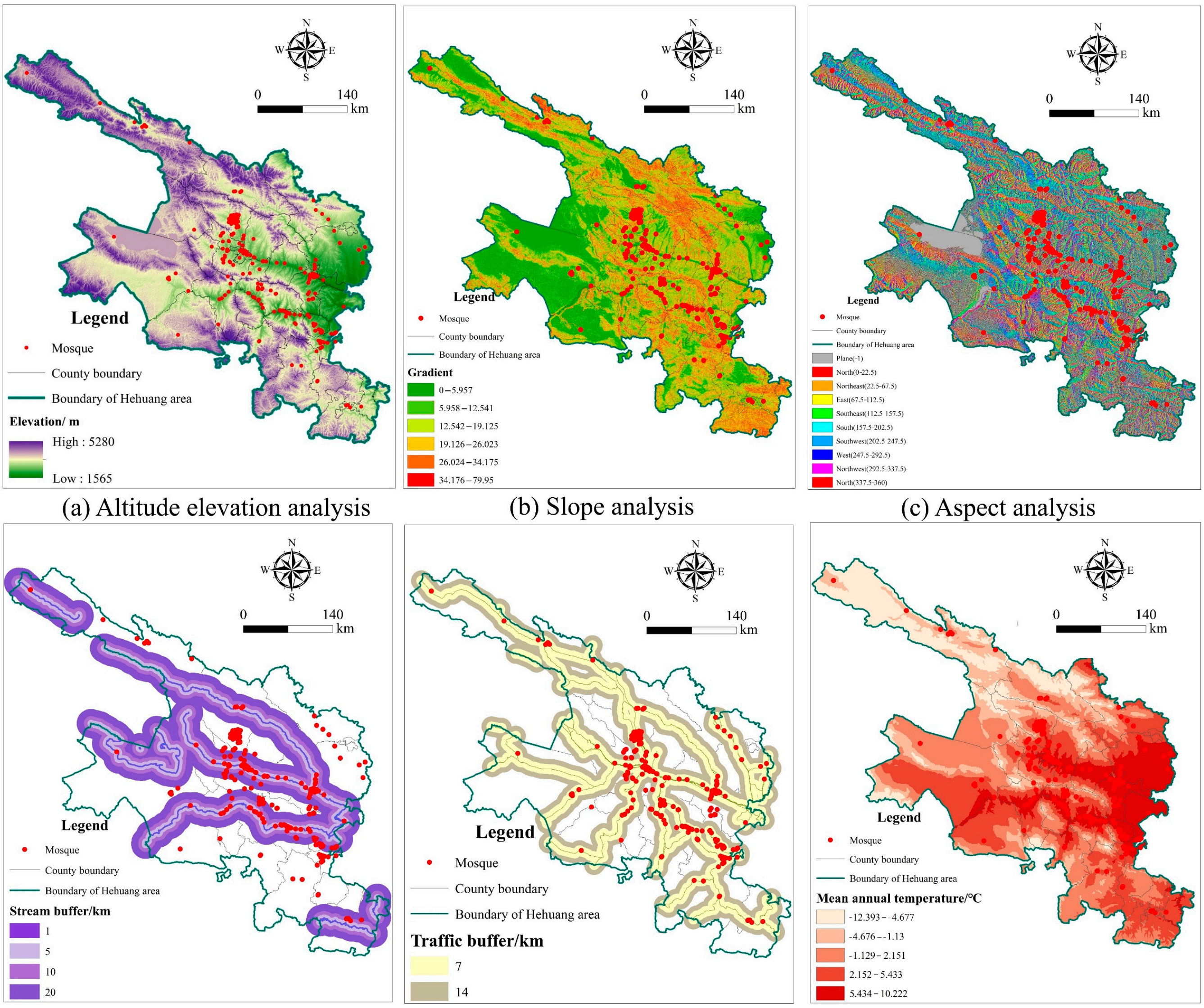
(4) Temperature and Precipitation Factors

Using annual average temperature and annual precipitation as analytical factors, we reclassified the data on these parameters using ArcGIS. By employing the natural break classification method, we categorized each into six levels. Subsequently, we overlaid and linked these levels with the spatial data of mosques to explore the correlation and coupling between the spatial distribution of mosques and the temperature–precipitation relationship (Figure 5f,g). Regarding temperature, we divided the annual average temperature into six categories: −12.39 °C to −5.86 °C, −5.86 °C to −2.94 °C, −2.94 °C to −0.11 °C, −0.11 °C to 2.54 °C, 2.54 °C to 5.54 °C, and 5.54 °C to 10.22 °C. As shown in Figure 6, the majority of mosques, totaling 151, are located in the 5.54 °C–10.22 °C range, accounting for 55.93% of all mosques; the next highest concentration, with 91 mosques, falls in the 2.54 °C–5.54 °C range, comprising 32.70% of the total. The analysis reveals that most mosques are distributed within the temperature range of approximately 2.54 °C–10.22 °C, particularly concentrated between 5.54 °C and 10.22 °C. This indicates that mosques are predominantly located in regions with mild climates and comfortable environments, often in valley areas characterized by dense populations and concentrated buildings, hence the higher number of mosques. For precipitation, we categorized annual rainfall into six levels: 186.56–320.24 mm, 320.24–394.06 mm, 394.06–453.92 mm, 453.92–513.77 mm, 513.77–575.62 mm, and 575.62–697.33 mm. According to Figure 6, the most mosques, numbering 100, are found in the 394.06–453.92 mm rainfall range, accounting for 37.04% of all mosques, followed by 83 mosques in the 453.92–513.77 mm range, making up 30.74% of the total. This shows that most mosques are located where the annual precipitation is between 400 and 500 mm. The average annual rainfall in the Hehuang Valley region is approximately 500 mm. This area, characterized by its suitable temperature and abundant precipitation, is conducive to human habitation, which in turn leads to a higher number of mosques.

The results indicate that traditional mosques in the Hehuang area are influenced by both temperature and precipitation. The valleys with suitable temperatures and abundant rainfall are central to the location of mosques, meaning that the site selection for mosques is in areas with superior temperature conditions and moderate precipitation. This demonstrates that the distribution of mosques has a significant environmental selectivity. The data suggest a positive correlation between temperature and the distribution of traditional mosques in the Hehuang area; that is, the higher the temperature, the greater the number and concentration of mosques. In terms of precipitation, mosques are distributed in areas with moderate rainfall, which are compatible with human living environments and suitable for habitation. Consequently, the number of mosques also tends to increase in these areas. Furthermore, under the influence of temperature and precipitation, the Huangshui Valley has seen substantial agricultural development. The immigrant trading population has settled here long-term, gradually adapting to the valley's climatic conditions. This has transformed the area into a multi-ethnic settlement. Among these, the Hui people have had a longer duration of residence and construction, leading to a relatively higher number of mosques in the area.

(5) Soil Type Factors

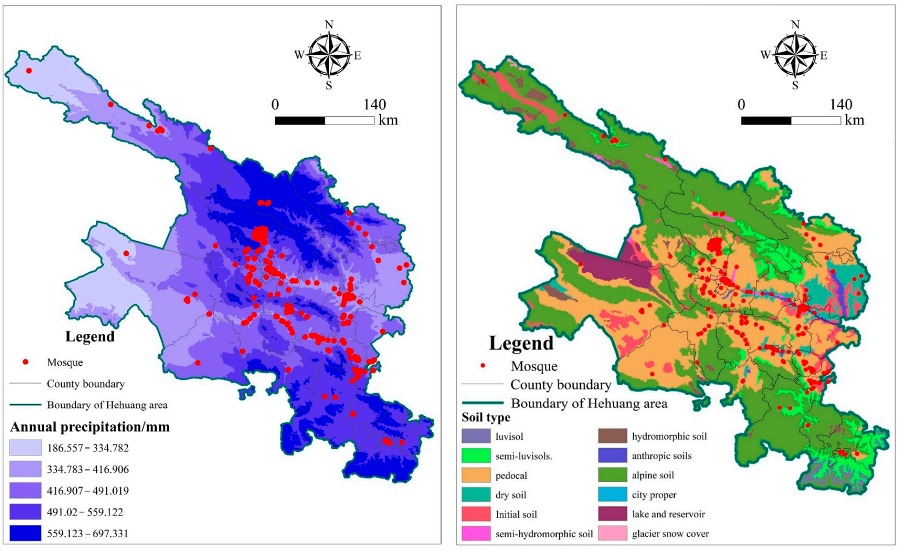
Soil is the most active site of material cycling and energy exchange on the Earth's surface, making areas with soil suitable for cultivation also ideal for constructing mosque buildings. The Hehuang area, with its extensive range and diverse geographical span, has a rich variety of soil types. Overlaying the soil types of the Hehuang area with traditional mosque architectural data generated a coupled relationship map between mosques and soil types (Figure 5h), encompassing 12 soil types: glacial snow cover, lake reservoir, urban area, alpine soil, anthropogenic soil, alluvial soil, semi-alluvial soil, immature soil, arid soil, calcic soil, semi-leached soil, and leached soil. The largest number of mosques, totaling 120, accounting for 44.44% of all mosques, are found on calcic soil, whereas scarcely any are located on glacial snow cover, lake reservoirs, or leached soil. Calcic soil is primarily found in North and Northwest China, specifically in the loess plateau regions of Western Shanxi and Northern Shaanxi, Eastern Longdong, South of the Liupan Mountains in Ningxia, Western Longxi, and in the vertical belts and intermountain basins of Qinghai, Gansu, and parts of Xinjiang. This soil, with a surface layer rich in humus and an accumulation of calcium (magnesium) carbonate, has a moderate texture, making it suitable for cultivation with a long growing season, hence the higher distribution of mosques. In contrast, glacial snow-covered soils are thin and have a long freezing period, poor aeration, and a neutral reaction, making them unsuitable for cultivation and hence less mosque distribution. However, there is a negative correlation between the number of mosques and certain soil types; for instance, leached soil, which is highly fertile and important for agricultural production, is less prevalent in the Hehuang area, limiting cultivation and development, and thus, fewer mosques are found on this soil type. From this analysis, it is evident that traditional mosques in the Hehuang area are primarily distributed on calcic soil.



(a) Altitude elevation analysis (b) Slope analysis (c) Aspect analysis

(d) Analysis of river buffer zone (e) Analysis of traffic buffer zone (f) Analysis of annual mean temperature

Figure 5. *Cont.*



(g) Analysis of annual precipitation (h) Analysis of soil type

Figure 5. Analysis of natural factors.

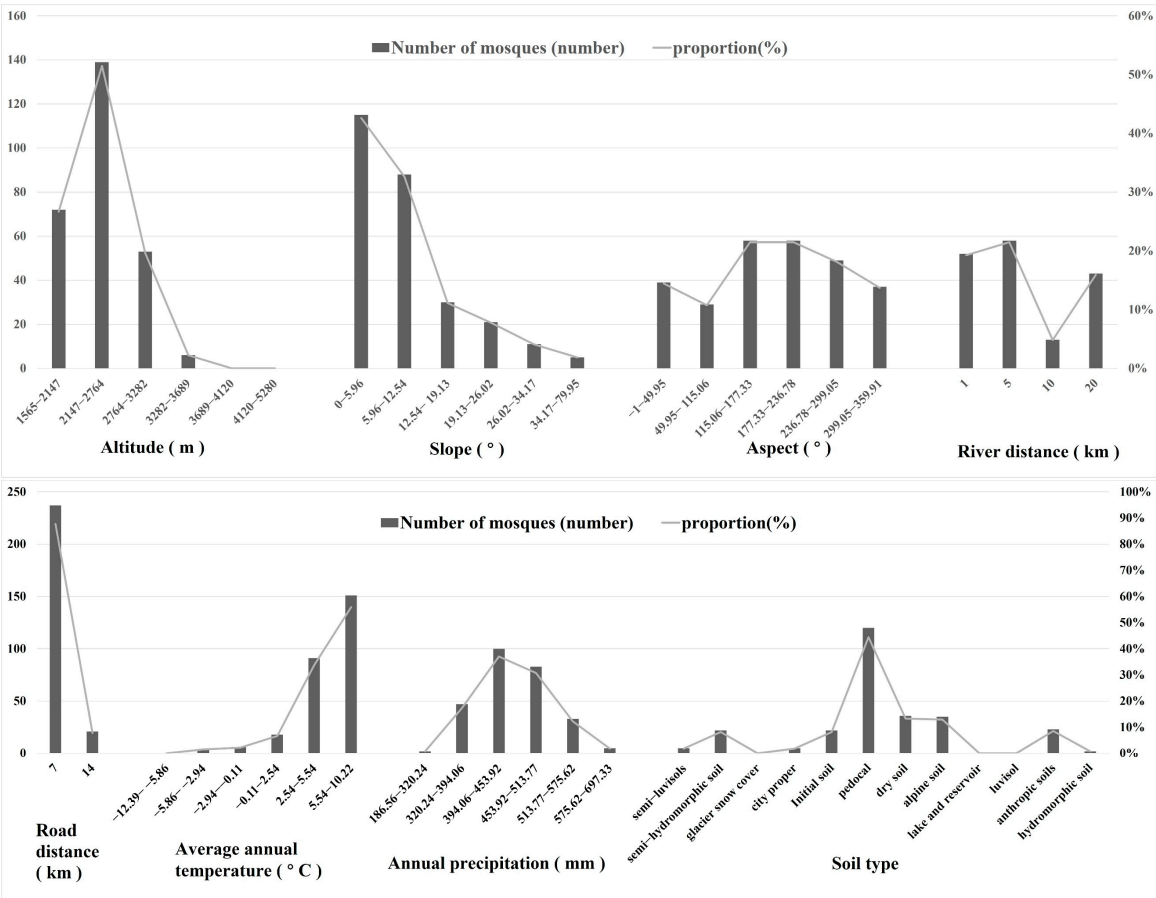


Figure 6. Mosque distribution and environmental directivity.

4.2.2. Human Environmental Factors

(1) Road Traffic Factors

In this study, we extracted four elements—expressways, national highways, provincial roads, and railways—in the Hehuang area as analytical factors for road transportation. Combining existing literature and field surveys, we focused on buffer zone analysis at distances of 7 km and 14 km, centered around transportation routes. We conducted buffer zone analysis for the road network in the Hehuang area. Subsequently, we overlaid the transportation buffer zones with mosque point data to investigate the correlation and coupling between the spatial distribution of mosques and road distances. From Figure 5e, it can be observed that there are a total of 258 mosques distributed within 14 km of road networks in the Hehuang area, constituting 95.56% of all traditional mosques in the area. The spatial distribution of traditional mosques in the Hehuang area is positively correlated with road distances. Most of them are concentrated within the 7 km range, totaling 231 mosques, which account for 87.78% of the total number of mosques. Within the 14 km buffer zone, there are 21 mosques, making up 7.78% of the total. This indicates that before 1993, over half of the mosques in the Hehuang area were situated near major transportation routes. Transportation serves as a vital link for both human and cargo movement. The Hehuang area, being an important gateway on the ancient Silk Road and facilitating trade between the East and the West, became a primary choice for numerous foreign Muslim merchants entering the Chinese mainland. Settling in the Hehuang area served as a convenient stopover point for their journeys, leading to the construction of mosques for their daily lives. These mosques were often strategically located near well-connected transportation routes, underscoring the significant impact of transportation accessibility on mosque spatial distribution.

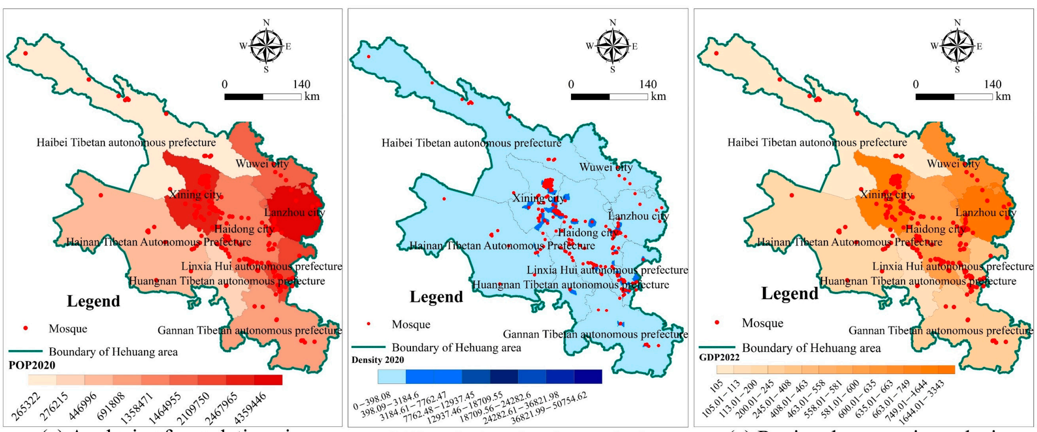
(2) Regional Demographic Factors

The Hehuang area is inhabited by various ethnic groups including Han, Tibetan, Hui, Mongolian, Tu, and Salar, exhibiting a pattern of “mixed living on a large scale and clustering on a small scale.” The Hehuang area is a typical region with a concentration of ethnic minorities, who make up about 46.98% of the total population of Hehuang. There is a positive correlation between the number of ethnic minority populations and the distribution of mosques. In areas with a higher proportion of Hui people, such as Haidong, Xunhua, Hualong, and Linxia, the number of mosques is correspondingly higher. The continuously increasing population is a fundamental factor in the expansion and development of traditional mosques in the Hehuang area. In places with denser populations, the concentration of buildings and the diversity of architectural types increase, which correspondingly leads to an increase in the number of mosques. As evident from Figure 7a,b, the population and density in the Hehuang area are primarily concentrated in the central and eastern areas of Hehuang. There are a total of 217 mosques, accounting for 80.97% of all mosques, mainly distributed in densely populated cities such as Xining and Lanzhou. According to the results of the seventh census, Xining has a permanent population of about 2.468 million, with a population density of 3615 people/km^2 and an urbanization rate of 79.87%. Lanzhou has a permanent population of about 4.359 million, with a population density of 7486 people/km^2 and an urbanization rate of 84.07%. It is obvious that both central cities in the Hehuang area have populations exceeding 2.4 million, with densities above 3500 people/km^2 and urbanization rates around 80%. This indicates a close correlation between the spatial distribution of traditional mosques and the population in the Hehuang area. Owing to its unique historical and geographical setting, the Hehuang area has over 660,000 Hui people, making it one of the significant origins of the Hui ethnicity in Northwest China. As the Hui population increases, so does the demand for residential space. This leads to the construction of mosques to accommodate the living needs. Consequently, as the spatial extent expands, the number of mosques is also gradually increasing. Data indicate that in the Hehuang area, there is a positive correlation between the number and density of the population and the density of mosque distribution. Where population density is higher and there are more people, there are also more mosques; in areas with lower population density, mosques are sparsely distributed. These less-developed areas cannot attract more population inflow and have fewer buildings. Most of these mosques are located in rural areas, were built in earlier times, and have been preserved due to the lower intensity of human activities. In areas with higher population densities, the Hui community and relevant departments continually renovate and construct new mosques. Therefore, in regions with larger populations, there tends to be a higher number of mosques.

(3) Regional Economic and Cultural Factors

From an economic perspective, as shown in Figure 7c, the economy is more developed in the central and eastern regions of Hehuang. The distribution density of mosques in these areas is higher, with a total of 186 mosques, accounting for 68.89% of all mosques. This preliminarily indicates that most mosques are located in economically developed areas, reflecting to a certain extent the fact that the spatial distribution of mosques is significantly influenced by regional economic development. However, in some areas, there is a negative correlation between the number of mosques and the level of economic development. For example, in Linxia Hui Autonomous Prefecture, the economy is relatively underdeveloped, but there is a large concentration of the Hui population. As a result, influenced by the population, there is a higher distribution of mosques. This indicates that the relationship between the spatial distribution of mosques and economic development levels is complex. Economic factors are not the sole determinants of the spatial distribution of mosques, but they are important influencing factors. Examining the geographical connection between mosques and GDP, it can be observed that the regional economic level has had a significant impact on the spatial distribution pattern of mosques. In recent years, with the continuous advancement of urbanization, most rural mosques have been gradually decreasing in number. Therefore, in regions experiencing economic development, the quantity of mosques has been affected.

From a regional cultural perspective, in the Hehuang area, where the three major river basins of the Yellow River, Huangshui River, and Datong River converge, there is an abundance of historical heritage and cultural resources. Diverse ethnic cultures coexist and blend harmoniously, with numerous ethnic groups residing here, creating unique cultural assets. Multiple cultures collide, interact, and merge in this area, collectively forming the diverse cultural system of the Hehuang area. The long-standing cultural history and agrarian civilization in the Hehuang valley have given rise to numerous cultural remnants, including the Ma Family Kiln Culture, Qi Family Culture, Xindian Culture, Kayo Culture, and others, totaling more than 2000 cultural remnants. The inclusive and open Hehuang culture has laid a solid foundation for the construction of mosques. Since the Sui and Tang dynasties, Arab and Persian merchants entered the Central Plains and the Hehuang area through the Silk Road of the Western Regions, introducing Islamic culture to the Hehuang area. To this day, Islamic culture continues to spread widely in the Hehuang area. As spiritual spaces of significance, mosques have gradually elevated their status throughout their development and evolution. With the increasing presence of Hui Muslims and Muslim followers in the Hehuang area, the number of mosques has correspondingly increased. Today, there are a variety of mosques and dome architecture in the Hehuang area.



(a) Analysis of population size (b)Population density analysis (c) Regional economic analysis

Figure 7. Analysis of population economic factors.

4.3. Interaction Analysis of Influencing Factors

In the Hehuang area, the number of traditional mosques is considered the dependent variable (Y), and various factors influencing the spatial distribution of mosques are treated as independent variables (x_i). Thus, an evaluation index system for the factors affecting mosque spatial distribution is established, with their influence and explanatory power indicated by the magnitude of q-values. This study aims to analyze the explanatory power and degree of influence of factors on the spatial distribution of traditional mosques in the Hehuang area. Eleven factors were selected as indicators affecting the spatial distribution of mosques: soil type (x_1), population number (x_2), population density (x_3), economy (x_4), precipitation (x_5), temperature (x_6), slope (x_7), elevation (x_8), aspect (x_9), rivers (x_{10}), and roads (x_{11}). Considering the development of the Hehuang area and the availability of actual data, the data for each factor were reclassified into grids. A geographic detector was then used to detect these factors, with the strength of each factor expressed by q-values. The results of this factor detection are shown in Table 4.

Table 4. Detection results of influencing factors of traditional mosques in Hehuang area.

Influencing Factors	Evaluating Indicator	q Statistic
x_1	Soil type	0.065
x_2	Quantity	0.215
x_3	Density	0.085
x_4	GDP	0.003
x_5	Annual mean precipitation	0.143
x_6	Annual average temperature	0.152
x_7	Average gradient	0.029
x_8	Mean elevation	0.040
x_9	Average aspect	0.007
x_{10}	Distance from river	0.003
x_{11}	Distance from road	0.001

The results indicate significant differences in the extent to which each factor influences the spatial distribution of traditional mosques. By arranging the q-values in descending order, we obtain $q\ (x_2) > q(x_6) > q(x_5) > q(x_3) > q(x_1) > q(x_8) > q(x_7) > q(x_9) > q(x_{10}) > q(x_4) > q(x_{11})$. The q-value of x_2 is the highest, followed by the factors x_5 and x_6, each with values greater than 0.1, indicating their significantly greater influence and explanatory power compared to other factors. Therefore, the main indicators affecting the spatial distribution of traditional mosques in the Hehuang area are primarily the population, followed by precipitation and temperature, which are key factors. To further explore the magnitude of interaction among various influencing factors, pairwise interactions of indicator factors were analyzed using a geographic detector to assess their impact on spatial distribution. As shown in Figure 8, the values of $q(x_5 \cap x_3)$, $q(x_5 \cap x_2)$, and $q(x_6 \cap x_5)$ are all greater than 0.3, demonstrating a trend of nonlinear enhancement in the interaction of dual factors, with their influence and explanatory power significantly exceeding that of single factors. Notably, the interactions between precipitation and population number, and precipitation and population density, are most significant, both exceeding 0.4; the interaction between temperature and precipitation follows, with a value of 0.38. Additionally, the interaction factors, $q(x_1 \cap x_2)$, $q(x_1 \cap x_5)$, $q(x_1 \cap x_6)$, $q(x_2 \cap x_6)$, $q(x_2 \cap x_8)$, $q(x_2 \cap x_{10})$, $q(x_5 \cap x_8)$, and others are all greater than 0.23, indicating significant impacts of interactions between soil and population number, soil and precipitation, soil and temperature, population number and temperature, population number and elevation, population number and rivers, and precipitation and elevation on the spatial distribution of mosques. Overall, population number, temperature, and precipitation are the dominant factors with the greatest interactive influence.

Additionally, the pairwise interactions between variable factors reveal the interplay among them, which is one of the most important conclusions in the paper. Combining Table 4 and Figure 8, the q statistics for population (x_2), precipitation (x_5), and temperature

(x_6) are 0.215, 0.143, and 0.152, respectively, indicating that the interactions between population, precipitation, and temperature are the dominant factors. Due to the rapidly increasing population in the Hehuang area, areas with higher populations have more mosques. The Hehuang area, located in the semi-arid inland regions of Northwestern China, relies heavily on temperature and precipitation for survival, leading to population and building locations typically in valleys with suitable temperature and moderate rainfall, where mosques are also prevalent. However, the q statistics for soil type (x_1), population density (x_1), slope (x_7), and elevation (x_8) are 0.065, 0.085, 0.029, and 0.040, respectively, showing that these factors have a secondary influence on the interactions and are considered fundamental but with weaker impacts. Therefore, the analysis reaffirms that the population factor is the predominant influence on the traditional clustering of mosques in the Hehuang area, followed by temperature, precipitation, elevation, rivers, and roads. The above eleven factors each influence the spatial distribution and developmental trends of traditional mosques in the Hehuang area to some extent. These factors are interconnected and mutually influential, collectively promoting the overall sustainable development of traditional architecture in the area.

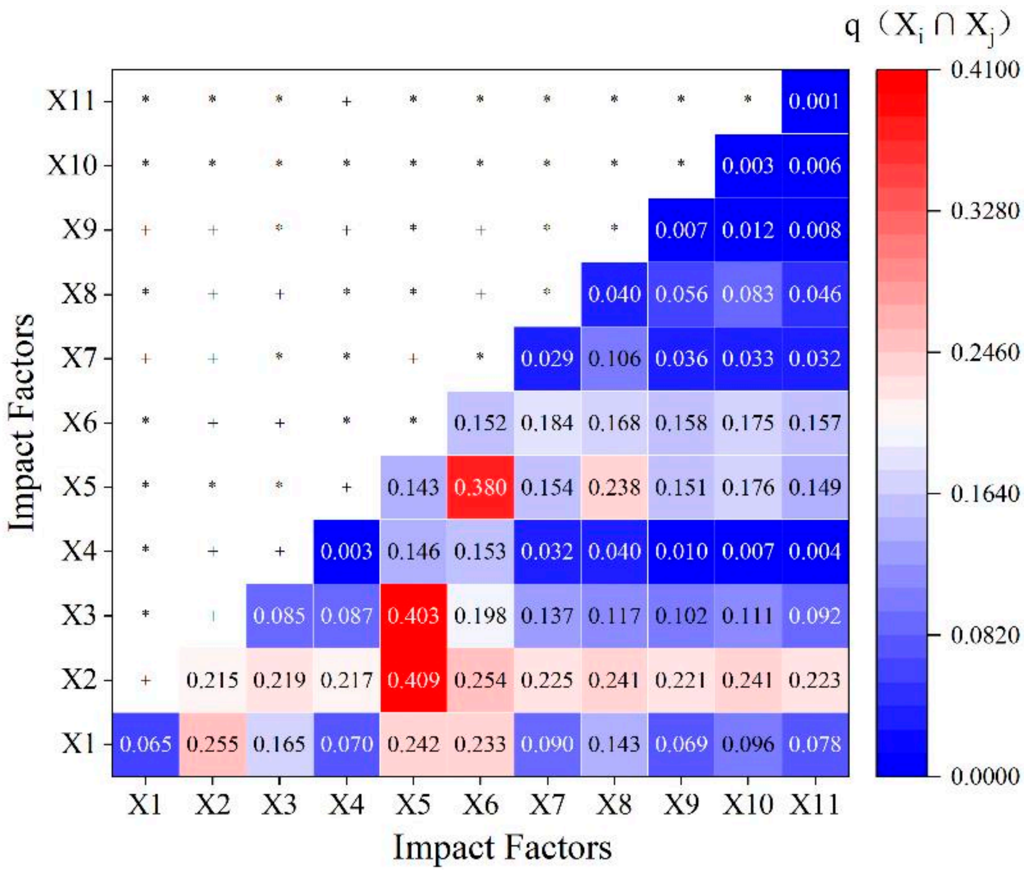


Figure 8. The detection results of the interaction between the influencing factors of the spatial distribution of traditional mosques in Hehuang area. **Note:** * denotes nonlinear enhancement [$q(x_i \cap x_j) > (x_i + x_j)$]; + denotes two-factor interaction enhancement [$q(x_i \cap x_j) > \text{Max}\,(x_i, x_j)$].

5. Discussion

Before 1993, mosques in the Hehuang area exhibited an overall spatial clustering pattern, with natural and human factors being the primary determinants of mosque distribution. This study, from the perspective of traditional mosque architecture, investigates the spatial distribution patterns of mosques in the Hehuang area and the factors influencing them. The unique geographical environment of the Hehuang area, especially its topography, natural climate, and historical culture, has had a significant impact on the formation and development of mosques. In addition to these external driving factors, the spatial distribution of mosques is also influenced by architectural layout, religion, and related policies. From a temporal perspective, the expansion and distribution of mosques are increasingly characterized by temporality. In the context of the blending and convergence of multiple ethnicities, factors such as political situations, economic benefits, and historical changes have gradually become key factors in the increase or decrease in mosque numbers. It is clear that the spatial distribution of mosque architecture is influenced by multiple factors. In the context of the development of diverse ethnic cultures today, the Hehuang area, as a typical ethnic corridor, plays a significant guiding role in ethnic cultural exchange and the coexistence of multiple ethnic groups in the entire Hehuang area.

(1) This study aims to explore the overall distribution characteristics and influencing factors of traditional mosque architecture in the Hehuang area. Research methods such as Global Moran's I, SDE, NNI, KDE, buffer analysis, etc. are primarily applied to the distribution characteristics of traditional mosques in the Hehuang area, whereas the geographic detector is mainly used to explore the dominant factors affecting the distribution of traditional mosques in this area. The study found that traditional mosques in the Hehuang area are generally clustered in their overall layout, with a few mosques sporadically distributed in the surrounding areas. Further investigation and research revealed that the layout of traditional mosques in the Hehuang area is significantly influenced by historical evolution. The majority of the population is concentrated in the Hehuang valley, resulting in a higher distribution of traditional mosque architecture in the valley. Conversely, the surrounding areas are prone to natural disasters, have fewer inhabitants, and are less conducive to construction and habitation, leading to fewer traditional buildings. These analytical results highly correspond to the actual situation, lending credibility to the research findings.

(2) Through the Global Moran's I analysis, it was discovered that the Moran's I value is 0.9242, proving that the distribution of traditional mosques in the Hehuang area is positively correlated with regional space, showing a clear clustering state. The Z-score of 30.5283 > 0 indicates that mosques in the Hehuang area are notably clustered. Local autocorrelation analysis revealed that the central Huangshui Valley presents a "high-high cluster", indicating a dense distribution of traditional mosques in this area, whereas the surrounding areas exhibit a "low-high cluster", indicating a more dispersed distribution of mosques. Combining the results of SDE and NNI studies, the SDE generally presents a "northwest-southeast" orientation in the Hehuang area, with a longer major axis and a shorter minor axis, and a flatness ratio of 0.58, indicating a flattened shape, which sufficiently demonstrates a significant clustering state of traditional mosque architecture in the Hehuang area, with a distribution tendency along a "northwest-southeast" direction at 45 degrees. Actual surveys found that the distribution of mosques is closely related to the topography of the Hehuang area, with cities in the Huangshui Valley mostly developing linearly along rivers; thus, traditional mosques in the Huangshui Valley are also linearly developed along the river. The NNI indicates an average observed distance of 3933.50 m, with a predicted average distance of 11,521.40 m, where the observed value is significantly lower than the expected value, further indicating a high degree of clustering of mosques in the Hehuang area. KDE analysis found that the highest mosque kernel density value can reach 182.90 mosques/km^2, forming two distinct core areas in the Hehuang area, one being a high-density clustering area mainly in the Huangshui Valley and the other being a core clustering area mainly in Xunhua County, with lower kernel density values in surrounding areas. Surveys revealed that the Huangshui Valley has a developed economy and a higher level of agricultural development, resulting in a greater number of mosque buildings, whereas Xunhua County, having a large Hui population historically, is influenced by cultural characteristics, forming another clustering area. By abstracting road traffic and river systems into linear elements and overlaying mosque point elements with generated roads and river buffer zones for

analysis, it was found that there are 166 mosques within 20 km of the riverbanks, confirming that the number of traditional mosques in the Hehuang area is positively correlated with rivers. There are 258 mosques within 14 km of roads in the Hehuang area, accounting for 95.56% of the total number of traditional mosques in the area, indicating that the distribution of traditional mosques is significantly influenced by ancient roads, confirming the positive correlation between the number of traditional mosques in the Hehuang area and road traffic.

(3) Using the geographical detector to statistically analyze the 11 selected factor indicators in the text aims to analyze the main driving factors affecting the distribution characteristics of traditional mosques. The analysis reveals that the population number (x_2) has the highest q value, followed by precipitation (x_5), and temperature (x_6) indicators, indicating that the main factors affecting the spatial distribution of traditional mosques in the Hehuang are population, followed by precipitation, temperature, and other factors. To further explore the magnitude of the influence and explanatory power among the affecting factors, it was found through interaction factors that nonlinear enhancement is significantly more prevalent than two-factor interaction enhancement, indicating an overall trend of nonlinear enhancement among the factors. From the interaction relationships of factors, it was found that population, temperature, and precipitation have the most significant mutual influence and the strongest explanatory power, indicating that population, temperature, and precipitation are the main factors affecting the distribution of traditional mosques in the Hehuang. It is noteworthy that historically, mosques served not merely as places of worship within Islamic communities but also had multiple uses. In the early Hehuang area, mosques functioned as vital educational centers that propagated ritual and cultural norms. Furthermore, mosques acted as community hubs where people gathered not only to pray but also to discuss community affairs and strengthen connections. Additionally, mosques participated in social welfare activities by distributing aid to those in need and sometimes managing farmland to support their activities. Most importantly, in the Hehuang area, mosques influenced urban layout and development, serving as centers of cultural and artistic growth and playing a crucial role in promoting Islamic art and architecture. These roles highlight the significant impact of mosques on the social, economic, and cultural life of Muslim societies.

(4) Currently, research on traditional mosques in the Hehuang area tends to be more concrete and focused on individual cases. However, this paper takes a holistic perspective from the viewpoint of heritage preservation. It extracts the spatial locations of traditional mosques in the Hehuang area from a planar perspective and discusses the spatial distribution characteristics and influencing factors of traditional mosques in the Hehuang area. The aim is to comprehensively grasp the development trends and evolutionary patterns of traditional mosques from a more macroscopic scale and to further analyze the specific distribution patterns and site selection conditions of traditional mosques in the Hehuang area from the perspective of influencing factors. At the same time, the Hehuang area includes both Gansu and Qinghai provinces. The comprehensive control and analysis of the spatial pattern of mosques not only reflect the differentiation patterns of mosques within the regional space but also to some extent promote regional sustainable development. Taking a regional holistic perspective, centered on the Hehuang area and oriented towards the northwest, we comprehensively control the architectural cultural heritage of the Hehuang area, revitalizing architectural cultural heritage within the region. This plays a positive and guiding role in the preservation and inheritance of architectural cultural heritage in the Hehuang area.

(5) Before 1993, a small number of mosques in the Hehuang area were located in remote areas such as suburbs and townships. However, with the impact of urbanization and modernization of agriculture and rural areas, mosques in these regions also face the threat of extinction. Therefore, the question of how to strengthen the preservation

of architectural cultural heritage in remote areas will be a research hotspot in the future. On the other hand, in the process of multi-ethnic interaction and integration in the Hehuang area, Islamic culture has gradually been influenced by various factors. The mosque architecture has gradually shifted from strip distribution to clustered distribution, and its aggregation has continued to strengthen.

(6) Traditional mosque architecture itself exhibits diversity, regionalism, and ethnic characteristics. In the past, the spatial characteristics and inherent logic of mosque architecture were clear, and the exchange and mutual learning among different ethnic cultures were sorted out. Historical culture and ethnic integration have been identified as the key factors for the growth, development, and inheritance of traditional mosques in the Hehuang area. Looking to the future, new technologies should be employed for the comprehensive management of the protection and development of mosques. Utilizing historical big data for the visual analysis of mosques can shift the study of architectural heritage from qualitative to quantitative, thereby enhancing the depth of research on traditional mosques in the Hehuang area. In the past, traditional historical verification and surveying methods were essential for the study of architectural heritage. However, with the intersection of multiple disciplines and the collaboration of diverse data, informatization and technologization will be the new trend in future research on architectural heritage.

(7) Additionally, though the POI data in this study have high timeliness and objectivity, clearly depicting the spatial structure and distribution characteristics of the Hehuang mosques, there are limitations due to different statistical scopes. For historical periods, precise localization and acquisition of POI data are not yet achievable. This paper, combining historical document reviews and comparisons with current mosques, acknowledges some errors in the data of mosques before 1993 that were collated. Owing to the historical records mentioning mosque construction dates being quite ancient, some mosques do not have specific construction years recorded, leading to deficiencies in the precision and completeness of data collected. Therefore, future research can appropriately strengthen the consideration of the construction years of mosques from various perspectives, to better reflect the dynamic evolutionary characteristics of mosques during different historical periods.

6. Conclusions

This paper studies 270 mosques in the Hehuang area before 1993, using the ArcGIS spatial analysis model to examine the spatial distribution characteristics and influencing factors of traditional mosques in the area. The following conclusions were found:

(1) Traditional mosques built in the Hehuang area before 1993 generally centered around the Huangshui Valley, exhibiting a distribution pattern of "central aggregation with peripheral dispersion." The spatial differentiation is distinct, with an overall uneven distribution but a clear concentration in certain areas. The overall spatial effect is significant, with the Huangshui Valley as the focal point, extending outward. In terms of the number of spatial distributions, cities like Xining, Haidong, and Linxia Hui Autonomous Prefecture have a higher concentration of mosques. The closer to the central Huangshui Valley, the more pronounced the clustering effect of mosques.

(2) Before 1993, traditional mosques constructed in the Hehuang area exhibited distinctive geographic distribution patterns. In terms of elevation, these mosques were predominantly clustered within the elevation range of 2147 to 2764 m above sea level, suggesting a preference for higher altitudes. Additionally, their positioning displayed a preference for gentle, sun-facing slopes with inclinations below 15 degrees, maximizing exposure to sunlight. Furthermore, concerning proximity to natural features, the mosques are primarily concentrated within a 20 km radius of rivers and a 14 km range from roads, highlighting their accessibility and the role of water bodies and transportation routes in their establishment. Moreover, they exhibited a penchant for regions receiving annual precipitation between 400 and 500 mm, indicative of a

preference for moderate moisture levels. Temperature-wise, these religious structures predominantly situated themselves in regions characterized by temperatures ranging from 5.54 °C to 10.22 °C, indicating a preference for moderate climates. Lastly, their prevalent distribution on calcareous soils underscores the significance of soil composition in their historical placement decisions. The observed distribution patterns of these mosques reveal a complex interplay between geographic, climatic, and infrastructural factors that influenced their historical establishment in the Hehuang area.

(3) The spatial distribution of traditional mosques built in the Hehuang area before 1993 was influenced not only by natural geographic factors such as topography, river systems, road transportation, temperature, and precipitation but also closely related to human environmental factors such as the population, economy, and culture. Among the numerous influencing factors, natural geography, cultural economy, and ethnic culture significantly affect the spatial distribution of traditional mosques in the Hehuang area. This is manifested in regions with more favorable natural locations, larger populations, greater population density, richer cultural resources, higher levels of economic development, and a substantial aggregation of Hui people; in such areas, the number of mosques is greater, and their distribution is more concentrated.

(4) Different influencing factors exhibit varying degrees of impact on the spatial distribution patterns of traditional mosques in the Hehuang area. Geographical detector results indicate that factors such as population, temperature, and precipitation exert more significant influence compared to soil composition, elevation, slope, aspect, and other factors. Population emerges as the dominant factor driving the clustering and distribution of mosques in the Hehuang area, and temperature, precipitation, elevation, proximity to rivers, and road accessibility constitute fundamental factors influencing the spatial distribution of traditional mosques in this region. The results of interaction analysis reveal two types of effects: double-factor enhancement and nonlinear enhancement. Among these, the coupled feedback relationship between precipitation and population, as well as that between precipitation and population density, demonstrate a stronger explanatory power in influencing the spatial distribution of traditional mosques. These findings underscore the complex interplay of various factors, where population dynamics, climate variables, and geographical features play pivotal roles in shaping the distribution patterns of traditional mosques in the Hehuang area.

Through the analysis and research of this paper, it has been found that both domestically and internationally, few scholars have studied traditional mosques in the Hehuang, and there is a lack of research from a macro and holistic perspective on the distribution characteristics and influencing factors of traditional mosques. In view of this, to further compensate for the previous research gaps and enrich the history of architectural heritage conservation in the Hehuang, this paper, based on the existing literature, focuses on discussing the spatial distribution characteristics and influencing factors of traditional mosques in the Hehuang, controlling the distribution trends of traditional mosques in the area from a holistic perspective. It provides technical references and theoretical support for the overall protection of traditional mosque architecture in the Hehuang, which is also a main innovation and significant contribution of this research. The study found that the complex geographical environment, concentrated population, and rich cultural characteristics of the Hehuang have had a certain impact on the distribution and protection of traditional mosques. The dependency, terrain, and clustering of mosques indicate that their protection and development are influenced by a variety of factors; hence, it is necessary to adhere to the principles of integrity and authenticity to achieve the overall protection of mosques' architectural heritage. Additionally, in the new era, it is even more crucial to promote the economic and industrial development of the Hehuang, accelerate population return, and establish comprehensive regulations to protect mosques' architectural heritage, which is also a focus of the next phase of research presented in this paper.

Author Contributions: Methodology, writing—review and editing, direction, and supervision, Q.X.; data collection, data analysis, and writing—original draft preparation, Y.H. and Q.X. completed this article together. All authors have read and agreed to the published version of the manuscript.

Funding: Funding was provided by the major projects of the National Social Science Fund (20&ZD209).

Data Availability Statement: Data are contained within the article.

Acknowledgments: We express our gratitude to the anonymous reviewers and editors for their professional comments and suggestions.

Conflicts of Interest: The authors declare no conflicts of interest.

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