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# Quantitative characteristics and influencing factors of Tibetan Buddhist religious space with monasteries as the carrier: a case study of U-Tsang, China

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## Abstract

Tibetan Buddhism has an inseparable connection with the spatial characteristics, development process, and human-natural environment of the Tibetan Plateau. This paper takes monasteries as carriers of Tibetan Buddhist culture in U-Tsang region which is one of the traditional geographical units of Tibet. Using geospatial analysis methods, this study explores the spatial quantification characteristics of Tibetan Buddhist monasteries and qualitatively and quantitatively analyzes the factors that influence the spatial distribution of monasteries. The results indicate that: (1) Political activities of human society influence the pattern of political power. Under the unique context of Tibetan theocracy system, the scope of political authority has a significant influence and affects the religious spatial pattern in the U-Tsang region throughout history. The distribution of monasteries in the U-Tsang region shows significant spatial differences at three sub-regional scales. (2) The religious spatial pattern in the U-Tsang is the result of the diverse interaction of human-natural factors. The results indirectly endorse that religious space is an inevitable product of the interaction between humans and the environment. (3) The religious spatial distribution patterns in the three major Tibetan regions have distinct characteristics, closely related to the superior conditions of their respective historical and geographical environments.

**Keywords** Tibetan Buddhist Monasteries, Spatial distribution, Religious space, Influencing factors, Tibetan regions

## Introduction

Tibetan Buddhism is a descendant of Indian and Chinese Buddhism [1]. Tibetan Buddhism originated in India. Following its introduction to Tibet, it assimilated the original religious rituals of the Tibetan region into its pre-existing doctrinal foundation. This resulted in a Tibetan religious belief system with distinct regional characteristics and ethnic features. Tibetan Buddhism is a core component of culture in Tibetan society, influencing behavioral

norms and value orientations throughout different historical periods and exerting a significant impact on the social structure of the Tibetan region [2]. As the dominant mainstream religion in the Tibetan region, it also serves as the economic backbone, political cornerstone, and educational foundation for Tibetan society, exerting profound influence on various aspects of the Tibetan region [3, 4]. Kapstein mentioned that Tibetan Buddhism is not only the active choice of indigenous essence over exotic cultures but also involves a profound transformation of ethnic sedimentation by foreign culture [5]. The unification of the Chinese Yuan Dynasty (1271–1368 A.D.) provided an opportunity for the external development of Tibetan Buddhism [6, 7]. Since Phags-pa was honored as the imperial preceptor by Yuan Dynasty,

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the system of theocracy also began to prevail in Tibetan regions, marking the beginning of a historical era that lasted for several centuries. The inclination of political power gradually became a symbiotic factor influencing and dominating the development of religion [8]. By the mid-to-late twentieth century, the global flow of culture has led to varying degrees of the spread of Tibetan Buddhism in North America, Europe, and Southeast Asia. During this dissemination process, Tibetan Buddhism has actively incorporated the geographical characteristics and social environments of each country, resulting in new interpretations and explanations of its doctrines [9]. Some Tibetans living overseas introduced Tibetan Buddhism to Japan, leading to the phenomenon of Japanese constructing Tibetan Buddhist monasteries [10]. In the United States, where the population has experienced multiple traumas from wars, people have started studying Tibetan Buddhism to seek spiritual liberation [11, 12]. Meanwhile, in Europe, Tibetan Buddhism often exists in the form of spiritual beliefs [13–15].

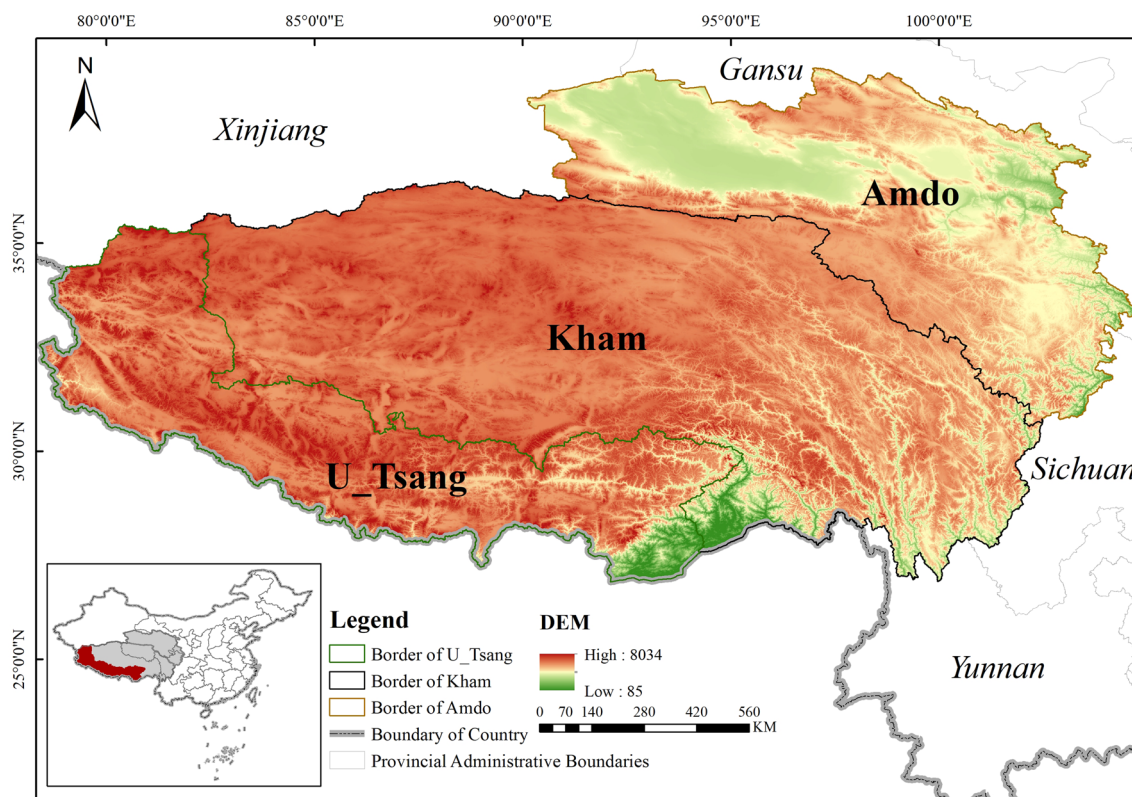
As the mainstream faith in Tibet, the evolution of Tibetan Buddhism culture is inextricably linked to the establishment of a specific religious space and the unique geographical environment of the snowy plateau. Religious development is materially manifested through the establishment and distribution of religious spaces. Feuerbach proposed that the basis of religious development lies in human dependence on religious beliefs, with the natural environment serving as the primal object of religious attachment [16]. Researchers believe that geographic patterns, as indicated by Zenlinsky [17], influence religious norms, shape religious landscape [18], and, as emphasized by Stump [19], impact the natural environment through their influence on human behavior. Atran's perspective adds that this interaction leads to the long-term adaptation of human settlements and society [20]. Religion relies on human activities for its dissemination and human survival cannot be separated from the support of the geographical environment. Thus, a 'trinity' organic combination of religious culture, human society and geographic space is formed. The interaction between religious culture and geographic environment produces the material place of religious space, which is affected by both geographic and human factors from site selection to construction.

The international research on Tibetan Buddhism and its religious space is relatively rich. Scholars from various research fields have conducted related studies from multiple perspectives, considering their respective disciplinary characteristics. The research spans across fields such as architecture [21, 22], history [23, 24], sociology [25, 26], economic [27, 28], psychology [29–31] and environmental studies [32–34]. Most of these studies focus

on the role of Tibetan Buddhism in spiritual practice and its impact on the improvement of social relationship [35]. As carriers of cultural heritage, Tibetan Buddhist monasteries are a focal point in the study of Tibetan Buddhist culture. Some scholars have undertaken comprehensive investigations into the construction and design of Tibetan Buddhist monasteries from the perspectives of architecture and culture [36, 37]. Guo approaches the study from the historical development of monasteries to explore their distribution [38]. Scholars such as Zhu [39] and Li [40] have qualitatively explored the temporal and spatial changes of Tibetan Buddhist monasteries in different dynasties through literature review. GIS has the ability to visually display historical change processes intuitively [41, 42]. Based on GIS theories, Yang analyzed the spatiotemporal evolution of mosques and Tibetan Buddhist monasteries in Qinghai Province [43], and Zhu et al. elucidated religious spatial patterns which including Tibetan Buddhism [44]. Xiao researched the characteristics of spatial distribution of 66 monasteries in Guoluo by use GIS to analyze the differences of land use types and landscape patterns between the monasteries and the settlements [45]. Fang et al. [46] and Chao et al. [47, 48] used GIS methods to qualitatively and quantitatively analyze the spatial distribution characteristics and influencing factors of Tibetan Buddhist monasteries.

In summary, it is evident that there is currently limited quantitative research on the spatial aspects of Tibetan Buddhism, with most outcomes leaning towards theoretical perspectives [49]. Tibetan Buddhist monasteries, serving as spatial carriers for the cultural transmission of Tibetan Buddhism. The differences in the distribution of monasteries reflect the spatial heterogeneity of local political power behind the development of Tibetan Buddhism during historical processes, and the spatial pattern of monastery distribution is the result of the comprehensive interaction between geographical and human factors. Supported by GIS, this study conducts quantitative analysis on the spatial distribution characteristics of Tibetan Buddhist monasteries and the influencing factors. Simultaneously, it aims to uncover potential political or historical influences behind the phenomenon of religious distribution.

U-Tsang is the political core of Tibet, and also the most prosperous area of religious culture in Tibet. At present, there is relatively little quantitative studies on the religion of U-Tsang. Some studies have explored the interrelationship between the development of these two ancient Tibetan regions through the historical comparison of U-Tsang and Kham and discussed the inherent inevitability of the formation of such a relationship [50, 51]. Hence, the development process of religious culture in the individual Wei-Tibetan region needs to be studied in greater



**Fig. 1** Overview of the study area

depth. As a result, this study takes Tibetan Buddhist monasteries in the U-Tsang region as the research object and analyzes the quantitative characteristics and influencing factors of religious spatial distribution from the perspective of historical geography with the GIS method. Considering the special status of the U-Tsang region in the entire Tibetan area, this study will have important guiding significance for the study of Tibetan Buddhist monastery culture.

**Materials and methods**

**Study area**

China’s jurisdiction over the Tibetan region has a long history. During the Yuan and Ming dynasties (1368–1644 A.D.), the central government established specific local institutions to separately manage the U-Tsang, Kham, and Ali regions (Fig. 1). During the Qing Dynasty (1636–1912 A.D.), in order to strengthen the central government’s control over Tibet, the imperial court dispatched officials to survey the borders between Tibet and surrounding provinces such as Sichuan, Yunnan, and Qinghai. Since then, the administrative divisions of Tibet have remained essentially stable and have continued to the present day. U-Tsang is the native land of the Tibetan people, constituting the fundamental component of the

Tibetan ethnicity. Geographically, U-Tsang is centered around the Yarlung Tsangpo River basin, characterized by fertile land and abundant rainfall, making it suitable for the cultivation of crops and serving as the cradle of Tibetan civilization.

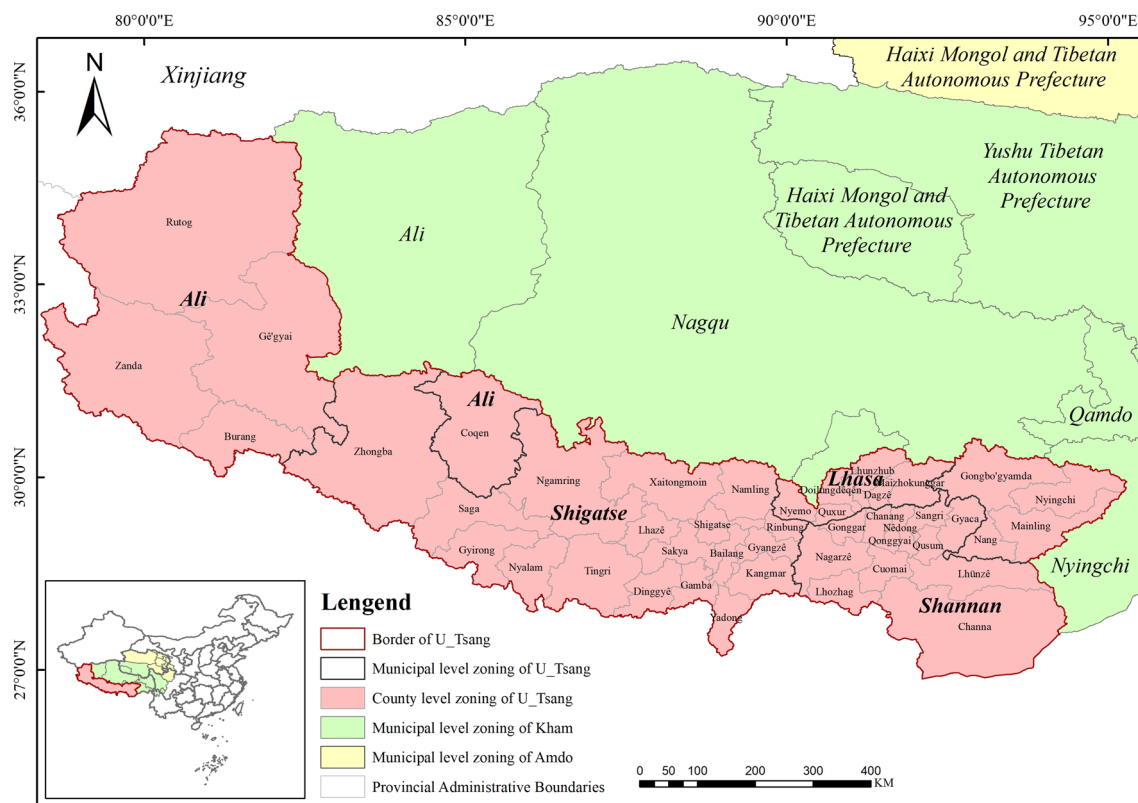
The boundaries of the U-Tsang region are primarily determined based on the Tibetan language dialect maps in the ‘Chinese Language Atlas’ and relevant maps in ‘A Historical Atlas of Tibet,’ combined with the current administrative divisions of China (Fig. 2).

**Data**

**Data sources**

The historical geographical data of Tibetan Buddhist monasteries in the U-Tsang region mainly includes three aspects: basic geographical data of monasteries, natural environment data, and socio-cultural data. Table 1 represents the data used in this study.

This data is obtained through three different approaches: literature review, online text mining, and field surveys. Firstly, historical text mining was employed to extract data related to the Tibetan Buddhist monasteries in the U-Tsang region. Monastery text data primarily originates from books as ‘Compendium of Tibetan Buddhist Monasteries in China.’ Considering that it is



**Fig. 2** Administrative division of the study area

**Table 1** Data list

Data name	Time	Data sources
Tibetan Buddhist monastery data	historical period to present	"Tibetan Buddhist Monasteries in China" series of materials, local chronicles, cultural relics, the official website of the State Administration of Religious Affairs, and field trips
Administrative division	2019	National Geomatics Center of China ( <a href="https://www.ngcc.cn/ngcc/">https://www.ngcc.cn/ngcc/</a> )
DEM	2011	National Geomatics Center of China ( <a href="https://www.ngcc.cn/ngcc/">https://www.ngcc.cn/ngcc/</a> )
River of class III or above	2015	National Geomatics Center of China ( <a href="https://www.ngcc.cn/ngcc/">https://www.ngcc.cn/ngcc/</a> )
Demographic data	1990	Socioeconomic Data and Application Center ( <a href="https://sedac.ciesin.columbia.edu/data/sets/browse">https://sedac.ciesin.columbia.edu/data/sets/browse</a> )
Historical River/Lake	1820	China Historical GIS ( <a href="https://chgis.fas.harvard.edu/">https://chgis.fas.harvard.edu/</a> )
Tea Horse Ancient Road Route	1820	China Historical GIS ( <a href="https://chgis.fas.harvard.edu/">https://chgis.fas.harvard.edu/</a> )
Tea Horse Post Station	1820	China Historical GIS ( <a href="https://chgis.fas.harvard.edu/">https://chgis.fas.harvard.edu/</a> )
Historical Administrative Divisions	1460&1820	"Chinese Historical Atlas" Tang Dynasty (618–907 A.D.) Picture Group-Tubo and Liao, Northern Song Dynasty (1127–1279 A.D.) Picture Group-Tubo Tribes

challenging to include all monasteries established in villages or counties, we referred to local chronicles. To supplement this information, we extensively consulted county chronicles. Furthermore, we utilized data retrieval methods to obtain the latest location and relevant information of the monasteries from the official websites of the National Religious Affairs Administration of China. Finally, to minimize discrepancies between the actual conditions of the monasteries and historical records, researchers conducted on-site investigations by visiting local monasteries and interviewing nearby residents in the U-Tsang region.

**Data processing**

*Research scale division* In order to delve into the spatial characteristics of the distribution of Tibetan Buddhist monasteries at different scales, this study, combines the historically recorded boundaries of the U-Tsang region with the current administrative boundaries, divides the U-Tsang region into three sub-regions: Anterior Tibet, Tsang and Ali (Fig. 3).

Lhasa and Shannan of U-Tsang are referred to as ‘Anterior Tibet,’ while the Shigatse is known as ‘Tsang.’ While the entire northern plateau of Tibet is called ‘Ali.’ During

the Qing Dynasty, various conflicts caused by the abolition of the 5th Dalai Lama Tsangyang Gyatso and the subsequent selection of the new Dalai during the reign of Emperor Kangxi triggered political instability in Tibet. In order to address the significant political crisis resulting from a series of events, Emperor Kangxi dispatched envoys to the Shigatse region in 1713 to officially recognize the 5th Panchen Lama as Panchen Erdeni at Tashilhunpo Monastery. From then on, the Qing Dynasty established a Panchen system in the Shigatse, creating a parallel system with the Dalai Lama system in Lhasa of Anterior Tibet. This led to the coexistence of two religious leaders, the Dalai Lama and the Panchen Lama, giving rise to the division between Anterior Tibet and Tsang in the political and religious space of Tibetan Buddhism. The Ali area is known as the ‘source of thousands of rivers’ and the ‘ancestor of thousands of mountains.’ Mount Kailash in Ali is considered the ‘center of the world’ in the doctrines of various religions, including Tibetan Buddhism. It has attracted numerous revered monks throughout history and served as the starting point for the propagation of Tibetan Buddhism.



**Fig. 3** Three sub-regions of U-Tsang

**Classification of monasteries** The impact range on the surrounding areas varies for Tibetan Buddhist monasteries of different scales. These spatial pattern differences significantly affect the development of Tibetan Buddhism in the surrounding areas. So it is essential to consider the hierarchical differences among monasteries. Classifying monasteries based on their basic information can help understand the variations in the roles and significance of different monasteries.

In the U-Tsang region, the classification of Tibetan Buddhist monasteries is primarily based on the following factors for comprehensive assessment and categorization: the scope of the congregation's origin, the number of subsidiary monasteries, the level of government attention, the historical significance of the monastery, the extent of the monastery's influence on the surrounding areas, the distribution range of the congregation, the size of the monastery, and whether the monastery has had a significant impact on the transmission of Tibetan Buddhism. After conducting a comprehensive evaluation of all Tibetan Buddhist monasteries in the U-Tsang through historical literature and relevant documentation, we have classified them into four levels of influence: Level 1 represents monasteries with top-level influence; Level 2 signifies monasteries with significant influence; Level 3 includes monasteries with substantial influence, and Level 4 comprises monasteries with general influence.

## Methods

### **Kernel density estimation**

Kernel density estimation (KDE) method is a commonly used technique in spatial pattern analysis [52]. Initially proposed by Rosenblatt and Emanuel as a non-parametric test method for estimating probability density functions [53] which is often used to analyze the distribution density of point data in the surrounding spatial area [54]. This study employs the KDE to analyze the overall distribution of Tibetan Buddhist monasteries in the U-Tsang region since the data for Tibetan Buddhist monasteries in the U-Tsang area is primarily in point format.

### **Standard deviation ellipse**

Standard deviational ellipse (SDE) is served as a versatile GIS tool used to reveal the spatial distribution trend of geographic features by identifying the distribution pattern and orientation around their geometric center [55, 56]. Analyzing the distribution area, shape oblateness, and distribution direction of the standard deviation ellipse can reveal the spatial distribution structure of geographical elements, the extensibility of their distribution centers, and then its spatial distribution direction trend can be explained in depth [57]. This article uses the standard deviation ellipse method to investigate the

distribution range and orientation of Tibetan Buddhist monasteries in the U-Tsang area.

### **Global Moran's I**

The Global Moran's I analysis method can simultaneously measure the spatial correlation of spatial data based on both the spatial locations and attribute values of the features [58]. Given a set of features with associated attributes, this method assesses whether the pattern expressed by the features is clustered or dispersed by calculating the Moran's I value, z Score, and p value. The Global Moran's Index typically ranges from  $-1$  to  $1$  [59]. The positive Global Moran's I represents the spatially cluster tendency of monasteries, when the distribution of monasteries is such that high-value areas are adjacent to low-value areas, the Global Moran's Index is negative. The z score and p value are used to determine whether the results are statistically significant.

### **Geodetector**

Geodetector is a geographic statistical method capable of detecting the driving forces behind the spatial differentiation of geographic objects [60, 61]. The core idea is that if a independent variable has a certain degree of impact on the dependent variable, it can be considered that the independent variable and the dependent variable have a certain spatial correlation in distribution. The geographical detector can not only analyze the main factors affecting the distribution of monasteries, but also detect the interaction of two factors on the dependent variable [62, 63]. In order to quantitatively analyze the factors influencing the distribution of Tibetan Buddhist monasteries in the U-Tsang region, this study selected six factors including elevation, slope, monastery orientation, distance to river, distance to the Ancient Tea Horse Road, and population density for specific analysis using the Geodetector. Figure 4 shows the methodological framework of the study.

## Results and discussions

### **Distribution pattern and characteristics of monasteries**

#### **Distribution pattern of multi-level monasteries**

We collected a total of 535 Tibetan Buddhist monasteries data in U-Tsang region, with 240 in the Anterior Tibet area, 241 in the Tsang region, and 54 in Ali region. The distribution of Tibetan Buddhist monasteries in the Anterior Tibet region is relatively concentrated, primarily forming a clustered pattern in the political core area of Tibet, Lhasa, and its surrounding regions. In the Tsang region, Tibetan Buddhist monasteries have a widespread distribution, with a distinct linear pattern in the southeast, less noticeable strip distribution in the central region along rivers, and a scattered pattern in the eastern

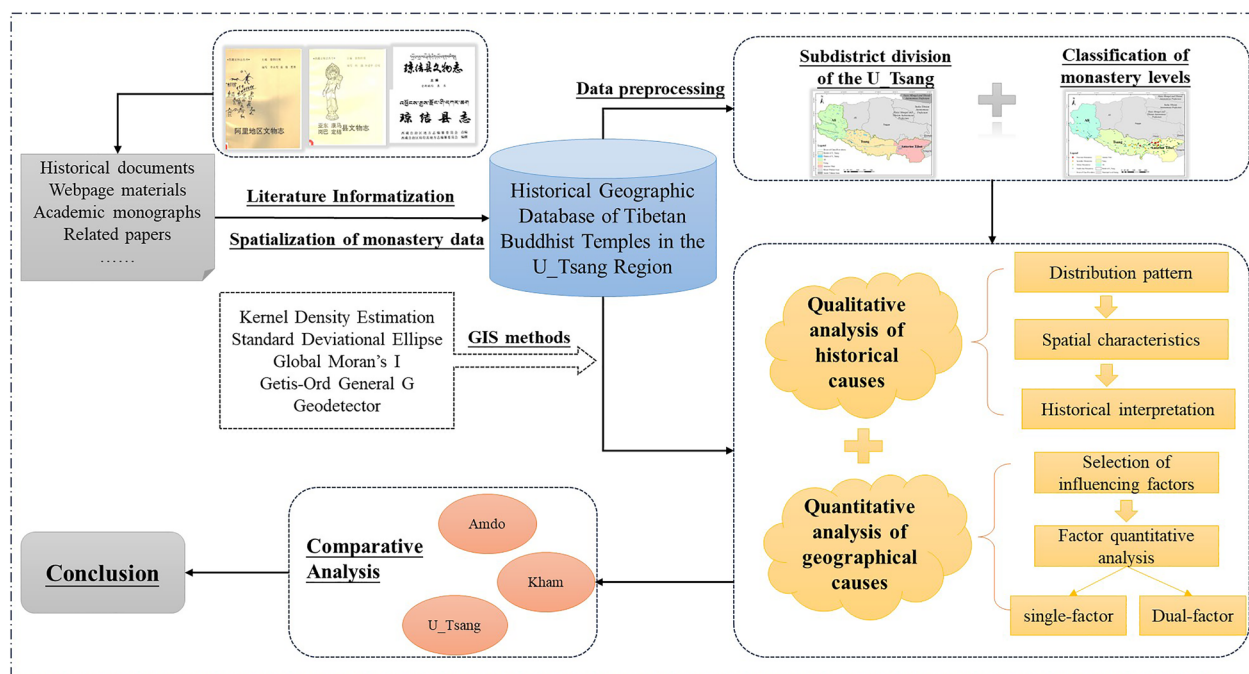


Fig. 4 Logical framework

and northeastern parts. The monasteries in Ali area are mainly distributed linearly along the river and have formed a relatively obvious gathering center in the southwest. As shown in Fig. 5.

In the U-Tsang region, there are 7 first-level monasteries with top-level influence, mostly located in Lhasa region and the northwest part of the Shannan. There are 25 s-level monasteries with great influence primarily distributed in Lhasa and Shigatse area. The second-level monasteries in Ali area are mainly distributed in Zanda that was once the political center of the ancient Guge Kingdom. Most of the 54 third-level monasteries with great influence are located in both Anterior Tibet and Tsang. The 449 fourth-level monasteries which have a general influence on the surrounding areas are widely distributed throughout U-Tsang region and most of them are concentrated in the Anterior Tibet. Tibetan Buddhist monasteries in the Tsang are scattered throughout this region, presenting a clustered pattern in the eastern near the Anterior Tibet. This clustering is related to the radiating effect of the Anterior Tibet, which serves as the political and religious center, on Tsang. In Ali region, fourth-level Tibetan Buddhist monasteries are mainly concentrated in the southern part of Zanda County, Gar County, and Purang County, exhibiting a distinct belt-like distribution. During the post-propagation period of Tibetan Buddhism, the Gelug sect received strong support from local powers such as the Guge royal family and

the Purang royal family, facilitating the establishment of Tibetan Buddhist monasteries in Ali. The spatial distribution of Tibetan Buddhist monasteries of different levels in U-Tsang region is shown in Fig. 6.

**Distribution density characteristics of monasteries**

This study utilized kernel density analysis to quantitatively analyze and visualize the clustering of Tibetan Buddhist monasteries in spatial distribution (Fig. 7). The results indicate that the peak density of monastery distribution is observed in Lhasa of Anterior Tibet, and the southeastern and southwestern parts of Shigatse in Tsang.

The high-density gathering center in Anterior Tibe is located in Chengguan District of today’s Lhasa. It possesses abundant natural resources, providing a favorable geographic environment, and substantial material foundation for the establishment of religious venues. In the mid-seventh century, when Princess Wencheng entered Tibet, this area was referred to as ‘Womatan’. After Songtsen Gampo unified Tibet and moved the capital here in 633 AD, he established renowned monasteries like Potala Palace and Jokhang Temple and other top influential monasteries in Tibet. With the increasing closeness between politics and religion, the establishment of religious sites and their affiliated sub-monasteries became an inevitable trend, especially in the Chengguan District as the political core. After the founding of People’s Republic



**Fig. 5** Overall distribution of Tibetan Buddhist monasteries in U-Tsang area

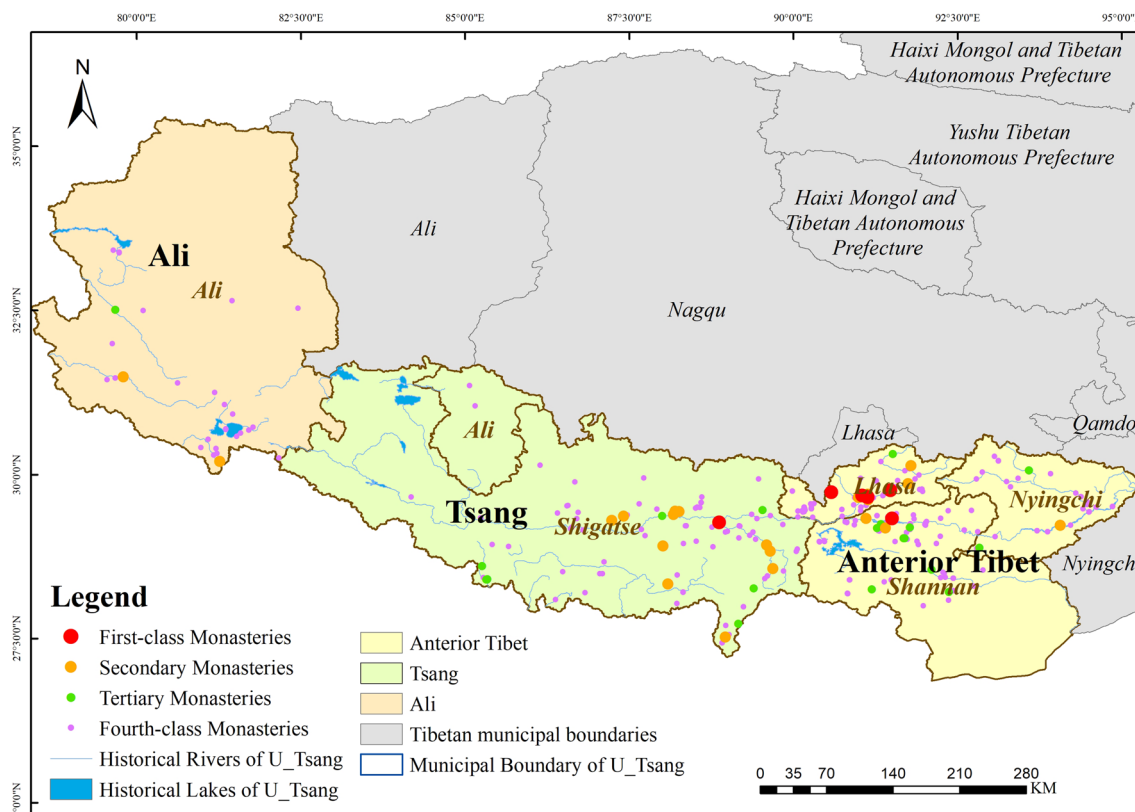
of China, during the many construction projects aided by the central government in Tibet, key monasteries in Chengguan District were maintained and some surrounding monasteries were restored. Most of the top influential monasteries are located in this area, forming a development pattern of Tibetan Buddhism with Chengguan District as the core and radiating influence on the surrounding areas.

The other two high-density aggregation centers are both located in Shigatse, Tsang. One is the high-density aggregation center of monasteries in the northeast, situated in today’s Xaitongmoin County. Xietongmen County is adjacent to Sakya County, the birthplace of the Sakya Sect, and the Brahmaputra River runs through the two counties. The natural conditions along the Yarlung Zangbo River are superior and the population is relatively densely distributed. It is an important place for Tibetan believers to hold religious activities and establish religious monasteries. According to historical records, during the Tubo period, Xaitongmoin County was the residence of the Benxin family, one of the six major noble families of Bon. Therefore, the development of Bon sect in this area has a profound historical origin. The present monasteries in Xietongmen County are generally small

in scale and the number of monks and nuns is not large. The inheritance and development of Bon and other sects of Tibetan Buddhism are affected by the interaction and integration of Buddhist culture.

The other high-density aggregation center of monasteries in Shigatse region is located in Gyirong County. The monastery aggregation density in this area is the highest among the three major sub-regions, indicating that the development of Tibetan Buddhist monasteries in this region is flourishing which is related to the long and splendid historical and cultural origins of the area. The northeast of Gyirong County has a flat terrain and fertile ecological resources, making it suitable for human activities and the establishment of material places. Historically, the line from Gyirong to Zongga has always been a gathering place of civilization. In terms of geographical and cultural connections, it has a natural relationship with the ancient Xiangxiang civilization. It has been influenced and radiated by it since ancient times. In the southeast direction, Gyirong County served as an important channel for cultural exchanges, trade, and even political alliances between ancient Tibet and Buddhist countries such as Nepal and India. The origin, spread and development of Tibetan Buddhism are inextricably linked



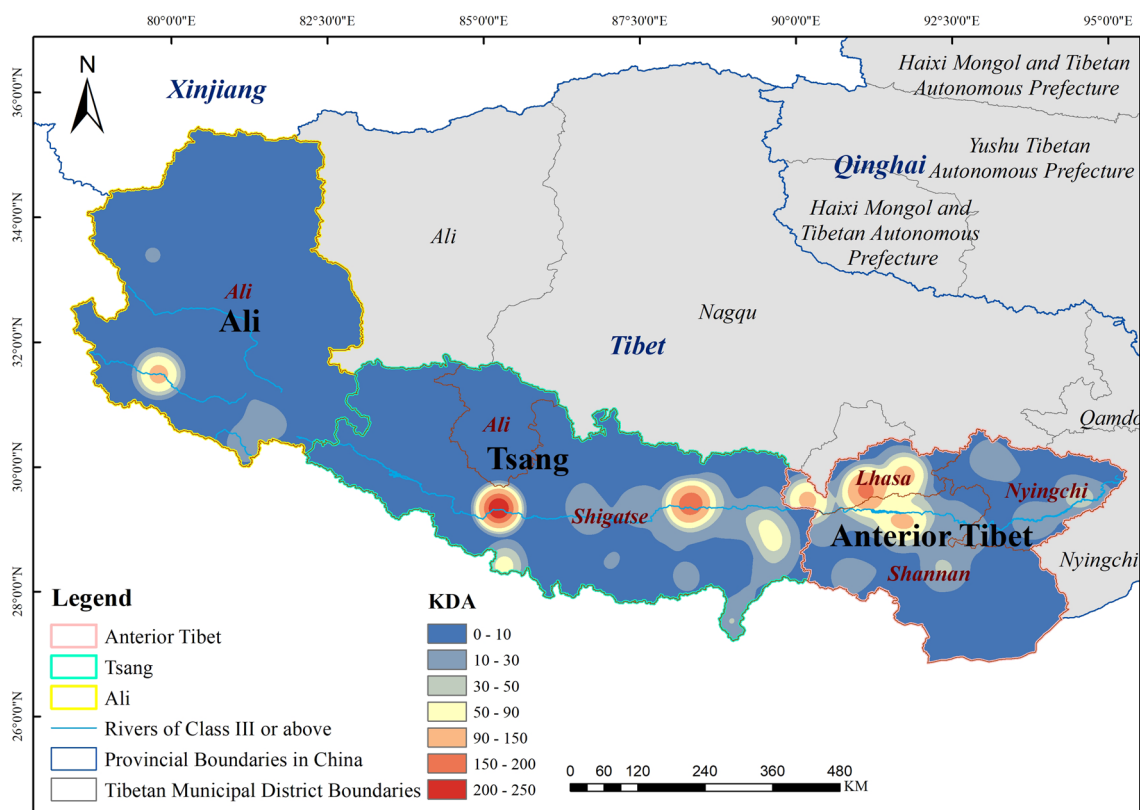


**Fig. 6** Distribution of monasteries at different levels in U-Tsang region

to Gyirong. During the Tubo period, Gyirong was the main post route from the Tang Dynasty to Tianzhu and the introduction of Buddhism into Tibet. Legend has it that Padmasambhava and Princess Chizun of Nepal both entered Tibet via this route. The entry of Princess Mandarava marked the official spread of Buddhism in Tibet. Since then, Gyirong has become an important channel for the spread of Mahayana Buddhism, holding a crucial historical position in the dissemination and development of Tibetan Buddhism. In the post-Tubo era, Gyirong established the prominent Gongtang regime. In response to the spiritual and ideological governance needs of the local feudal lords, a large number of monasteries were established in Gyirong County. From the early eleventh century to the mid-seventeenth century, Gyirong had been the center of the Gongtang regime for more than 600. During the Gongtang regime period, unprecedented political, economic, and cultural development resulted in the creation of a large number of ancient civilizations which including Tibetan Buddhist monasteries. In Tibetan history, Gyirong was the place where many major events took place. Many political and religious figures have met here, making this place a unique area for religious development in Shigatse region. These specific

natural and historical conditions have given birth to a strong religious atmosphere and long historical culture in this area. The establishment of many Tibetan Buddhist monasteries has become one of the unique religious and cultural landscapes in Gyirong.

The particularity lies in that the monasteries in the Ali region only form a low-density cluster center in the Zanda County. Zanda County is the birthplace of the Xiangxiong civilization and has given birth to the ancient Guge civilization. Adjacent to Zanda County, Purang County was also the location of the ancient Purang Kingdom. In the thirteenth century, Ali became a major area for the spread of the Drigung Kagyu. The Guge King strongly supported the development of Drigung Kagyu in his territory and honored the leader of the Kagyu sect as the king’s teacher. In the next one or two hundred years, the Kagyu sect has always been the mainstream sect in Ali region. It was not until the fifteenth century that the Gelug sect was founded and spread to Ali area, and a large number of Gelug sect monasteries were established in Ali. In order to adapt to the historical trend and preserve their own development, many famous original monasteries gradually converted to the Gelug sect in order to seek better survival and development.



**Fig. 7** Kernel density analysis results of monasteries in U-Tsang area

**Distribution direction characteristics of monasteries**

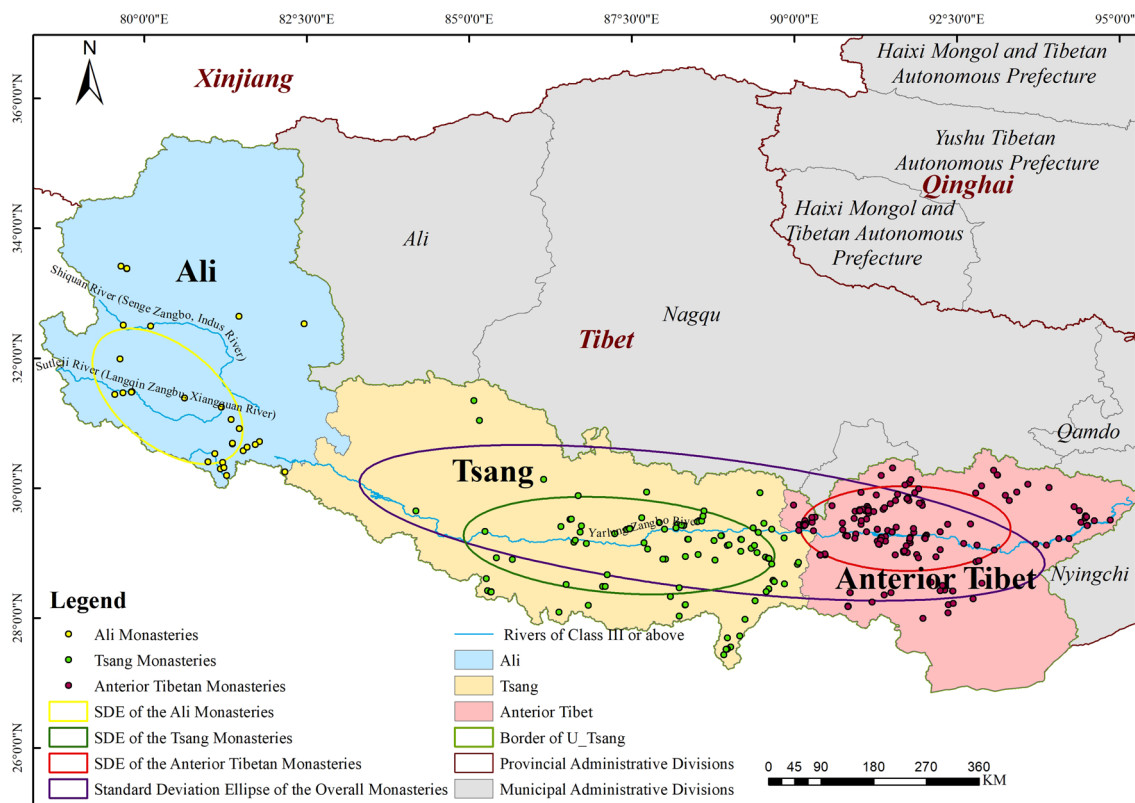
The distribution direction of monasteries in U-Tsang region can be obtained through the analysis of standard deviation ellipses for Tibetan Buddhist monasteries at different scales. Figure 8 shows that the distribution of Tibetan Buddhist monasteries exhibits obvious directionality and the monasteries are generally distributed in a northwest-southeast direction in the entire U-Tsang area. From the perspective of the existing spatial pattern of monastery distribution in U-Tsang region and its correlation with the natural geographic environment, monasteries are predominantly concentrated in the eastern parts of Lhasa in Anterior Tibet and Shigatse of Tsang. These areas have relatively flat terrain and numerous rivers, making them suitable for the establishment of Tibetan Buddhist monasteries. From a macro perspective, the distribution direction of monasteries in U-Tsang region aligns with the main flow direction of Brahmaputra River and generally running parallel to this river.

Conducting a standard deviation ellipse analysis on the monasteries in the three major sub-regions of U-Tsang region yielded the results shown in Fig. 8. The results indicate that the Tibetan Buddhist monasteries

in Anterior Tibet are distributed from west to east. The directional distribution of monasteries in Tsang region is more pronounced than in Anterior Tibet region, aligning in a northwest-southeast direction along the main rivers in the area. Due to topographical reasons, monasteries are mainly concentrated in the southern part of Ali area with low terrain. Ali has many major rivers such as Shiquan River, Xiangquan River, and Maquan River, providing abundant water resources. The main distribution direction of Tibetan Buddhist monasteries is northwest-southeast along Xiangquan River that runs through the entire Zanda County. Zanda County, as the site of the ancient Guge Kingdom, was once a flourishing area for various sects of Tibetan Buddhism, especially Drigung Kagyu and Gelug that were favored by the ruling classes of the ancient Guge Kingdom and Purang Kingdom. As a result, numerous monasteries were established in present-day Zanda County and Purang County in the lower part of Ali.

**Exploring the agglomeration mode of monasteries**

In order to conduct a more in-depth qualitative and quantitative analysis of the distribution patterns of



**Fig. 8** Results of standard deviation ellipse analysis

Tibetan Buddhist monasteries in U-Tsang region, this study employed the Global Moran’s I method to analyze the agglomeration trends of Tibetan Buddhist monasteries at different scales. The results are presented in Table 2.

The results of spatial autocorrelation analysis indicate that the distribution of Tibetan Buddhist monasteries in U-Tsang region exhibits clustering tendencies, but there are slight differences in these clustering patterns. The Moran’s I analysis for the three major sub-regions shows that the correlation of monasteries in Anterior Tibet region is most obvious, followed by Ali region, while the correlation in Tsang region is the weakest. The larger the Z value is, the more obvious the dispersion trend is. Therefore, based on the Z scores, we can categorize the degree of clustering for monasteries into

‘Dispersed-Clustered, Concentrated-Clustered, and Normal-Clustered’ patterns. Overall, Tibetan Buddhist monasteries in U-Tsang region exhibit a ‘normal-clustered’ pattern. At the scales of the three sub-regions, monasteries in Tsang region show the most pronounced dispersion, Ali region exhibits a weaker dispersion trend and the Anterior Tibet region demonstrates a normal spatial clustering pattern.

**Influencing factors of the monastery distribution**

*Natural factor selection*

Topographic factors are long-term, gradually formed natural elements that do not undergo rapid changes in short term. They are the most direct factors influencing the infrastructure development, layout morphology, and

**Table 2** Results of spatial autocorrelation analysis in U-Tsang

Research scale	Moran’s I	Variance	Z score	P value	Agglomeration trend
U-Tsang	0.20	0.00	36.92	0.00	Normal-Clustered
Anterior Tibet	0.52	0.00	33.27	0.00	Normal-Clustered
Tsang	0.34	0.00	40.58	0.00	Dispersed-Clustered
Ali	0.49	0.00	19.15	0.00	Concentrated-Clustered

distribution trends of monasteries in the Tibetan region. Through the density and directional analysis of the Tibetan Buddhist monasteries distribution in the previous chapters, it can be observed that factors such as rivers affecting resource acquisition, altitude determining human activity areas, slope affecting terrain undulations, and aspect determining the orientation of monasteries, etc. play a crucial role in their establishment. Therefore, we have chosen elevation, slope, monastery orientation, and distance to rivers as the four main natural factors for analysis.

(1) *Elevation* Elevation determines the difficulty of building Tibetan Buddhist monasteries and is also an important factor affecting the spread of religious culture in the region. Table 3 is obtained by counting the number of monasteries located at different elevation. The results indicate that elevation is not a decisive factor influencing the distribution of monasteries. The fact that only 17 Tibetan Buddhist monasteries are situated in the region above 5000 m elevation, which accounts for 44.5% of U-Tsang region, further supports this perspective.

(2) *Slope* Slope is commonly used to describe the steepness of Earth’s surface, which to a certain extent will affect the location and scale of Tibetan Buddhist monasteries. This study refers to the classification rules for slope in China’s ‘Technical Regulations for Land Use Survey’. The slope in U-Tsang region was reclassified into five levels:  $\leq 2^\circ$ ,  $2^\circ-6^\circ$ ,  $6^\circ \sim 15^\circ$ ,  $15^\circ \sim 25^\circ$  and  $\geq 25^\circ$  that corresponding to flat, gentle slope, slanting slope, sharp incline, and cliff respectively. Table 4 shows the number of monasteries at different slope levels.

The slope analysis results indicate that although Tibetan Buddhist monks in Ali may choose to build

monasteries on steep cliffs with slopes above  $15^\circ$ , there are only 7 such monasteries. This is associated with the higher difficulty of construction, challenges in transporting materials, difficulties in monks’ access to production, and living resources in areas with steep slopes. Monasteries are more commonly established in relatively flat areas. In regions with slopes less than  $15^\circ$ , 528 Tibetan Buddhist monasteries have been established, accounting for 98.7% of the total number of monasteries. In flat areas, only 95 Tibetan Buddhist monasteries were built that representing a mere 17.8% of the total. This seems contrary to the traditional impression that monasteries are mostly built on plains. This is not only due to the complex terrain of the Tibetan region but is also related to certain doctrines in Tibetan Buddhism that advocate ‘austere practice, sitting in meditation’ and other spiritual practices leading most monasteries to be built near mountains.

(3) *Terrain undulation* Terrain undulation is an important indicator for classifying landforms in international mapping [64–67]. It originated from the topographic cutting depth proposed by the Geography of the Soviet Academy of Sciences in 1984. This natural element is one of the factors that cannot be ignored when exploring the distribution of Tibetan Buddhist monasteries in the U\_Tsang area. Terrain undulation refers to the difference between the highest and the lowest elevation in a specific area. It is a macroscopic indicator that describes the terrain characteristics of a region. Using the neighborhood analysis function of DEM to calculate the terrain undulation. The larger the value, the more obvious the terrain undulation, and vice versa, the flatter it is. This article divides the terrain of U\_Tsang into four levels based on the calculated terrain undulation, namely hills ( $\leq 250$  m), small undulating mountainous (250~500 m), mid undulating mountainous (500~750 m), and great undulating hills

**Table 3** Statistics of Tibetan Buddhist monasteries at different elevation levels

Elevation (m)	< 1000	1000–2000	2000–3000	3000–4000	4000–5000	> 5000
Area proportion	1.2	2	1.5	4.3	46.5	44.5
Number of monasteries	0	0	12	238	268	17
Quantity proportion	0	0	2.2	44.5	50.1	3.2

**Table 4** Statistics of Tibetan Buddhist monasteries under different slope levels

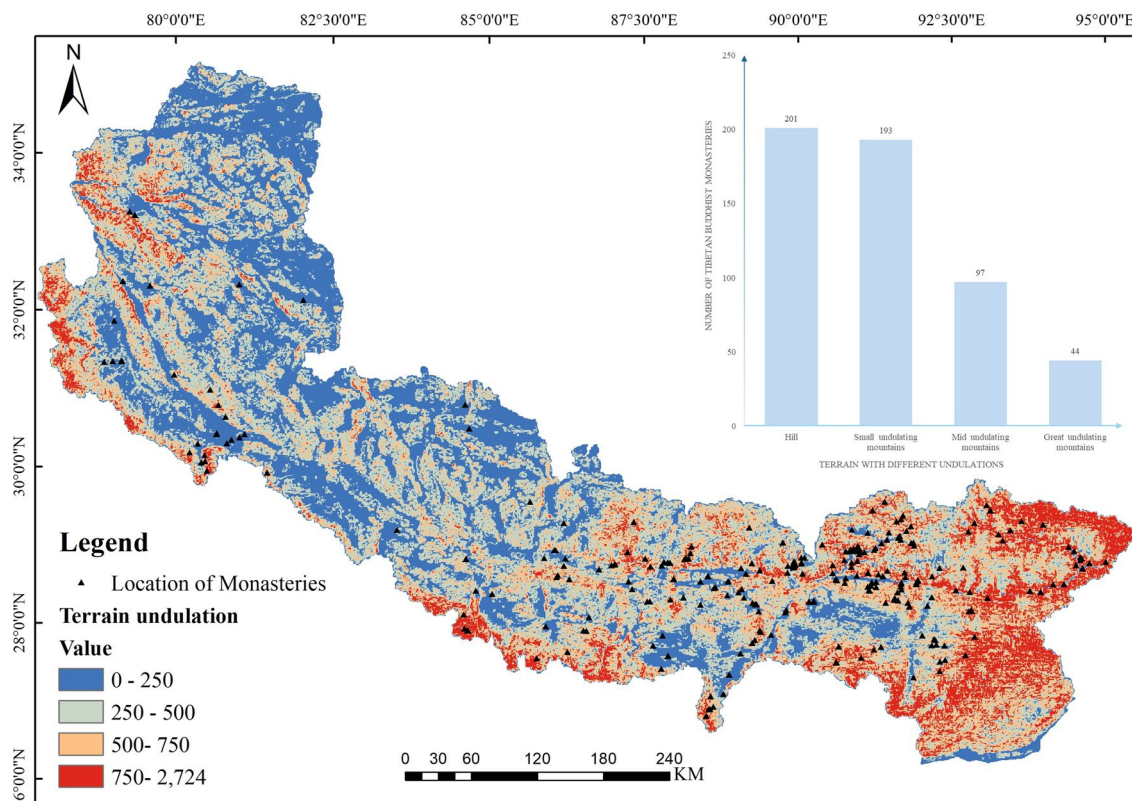
Slope	$\leq 2^\circ$	$2^\circ-6^\circ$	$6^\circ-15^\circ$	$15^\circ-25^\circ$	$\geq 25^\circ$
Category of slope	plain	gentle slope	slanting slope	sharp incline	cliff
Number of monasteries	95	284	149	7	0
Monastery proportion	17.8	53.1	27.9	1.3	0.0

(>750 m). This article uses ArcGIS to calculate the terrain undulation in the U-Tsang area and then overlays it with the distribution data of Tibetan Buddhist monasteries to obtain the results as shown in Fig. 9 which show that most Tibetan Buddhist monasteries are located in hills and small undulating mountainous areas with a total of 394, accounting for 73.6%. While the number of Tibetan Buddhist monasteries in complex mountainous areas with great terrain undulations is only 44. This research shows that monasteries are located more in areas with less undulating terrain, which is more suitable for general monasteries to reduce the difficulty of living. However, there are still monasteries located even in great undulating mountainous areas with terrain undulations larger than 750 m which means that no matter how high the altitude is and how complex the terrain is, Tibetan Buddhism still plays the role of spiritual pillar in the lives of the Tibetan people.

**(4) Monastery orientation** Slope aspect has a significant impact on mountainous ecosystems. The orientation of mountains affect the duration of sunlight and the intensity of solar radiation. In U-Tsang region, the aspect has a crucial influence on ecological resources such as crops and forests, and these ecological resources play an important role in providing natural sustenance for Tibetan Buddhist

monasteries. U-Tsang region generally has a high altitude and is cold throughout the year. In such an environment, the construction of monasteries needs to consider factors such as sunlight and precipitation to ensure temperature conditions and provide support for monastery life. The overlay analysis of slope aspect and monastery distribution in U-Tsang region reveals that about one-third of the Tibetan Buddhist monasteries are facing west, while those facing northeast are the least numerous. This is because north-facing shaded slopes have shorter sunlight duration and are generally colder. There are fewer monasteries located on the semi-shady slopes facing the northeast and northwest. Most monasteries are built on sunny slopes facing south or semi-sunny slopes facing southeast or southwest. Field survey shows that monasteries tend to be established in areas sheltered from the wind and facing the sun to maximize the absorption of solar radiation, ensuring the livelihood and survival needs of the monks residing in the monasteries [68].

In-depth analysis of the monastery orientation of Tibetan Buddhist monasteries in U-Tsang region, considering their different sect affiliations that reveals distinct orientation trends among various sects. Mainstream sects such as Gelug, Nyingma, and Sakya tend to build monasteries facing west and southwest. Other sects



**Fig. 9** Analysis of the impact of terrain undulation on the distribution of monasteries

lean towards establishing monasteries facing south and southeast. The analysis of slope aspect for Tibetan Buddhist monasteries that combined with their respective sectarian affiliations was further divided to generate the orientation statistics (Fig. 10) for monasteries in U-Tsang region. The statistical results reveal varying orientation trends among monasteries of different sects within Tibetan Buddhism. Mainstream sects such as the Gelug, Nyingma, and Sakya predominantly establish monasteries facing west and southwest. Other sects prefer to build their monasteries in south and southeast orientations.

(5) *Rivers* River systems provide essential water resources for the Tibetan people and are a crucial factor influencing the distribution of Tibetan Buddhist monasteries. There are numerous river systems in U-Tsang with Yarlung Tsangpo River dividing it into northern and southern parts. There are also major rivers such as

Xiangquan River and Shiquan River in the territory. Considering that smaller river systems are significantly influenced by historical droughts which may experience interruptions, drying up, diversions etc. We selected rivers of Class III and above in U-Tsang region as the primary analysis objects. By calculating the distance to rivers, it is categorized into seven levels and the number of monasteries within different distance ranges is counted to obtain the results (Table 5). The results indicate that within areas with a distance of less than 250 m from rivers, there are 307 Tibetan Buddhist monasteries which accounting for over half of the total monasteries. There are 411 monasteries within 500 m from the monasteries that accounting for 76.8% of the total. This suggests that the distance to rivers significantly influences the selection of monastery locations. It is evident that there is a clear spatial negative correlation between the distance to rivers and the density of monastery distribution which is closer proximity

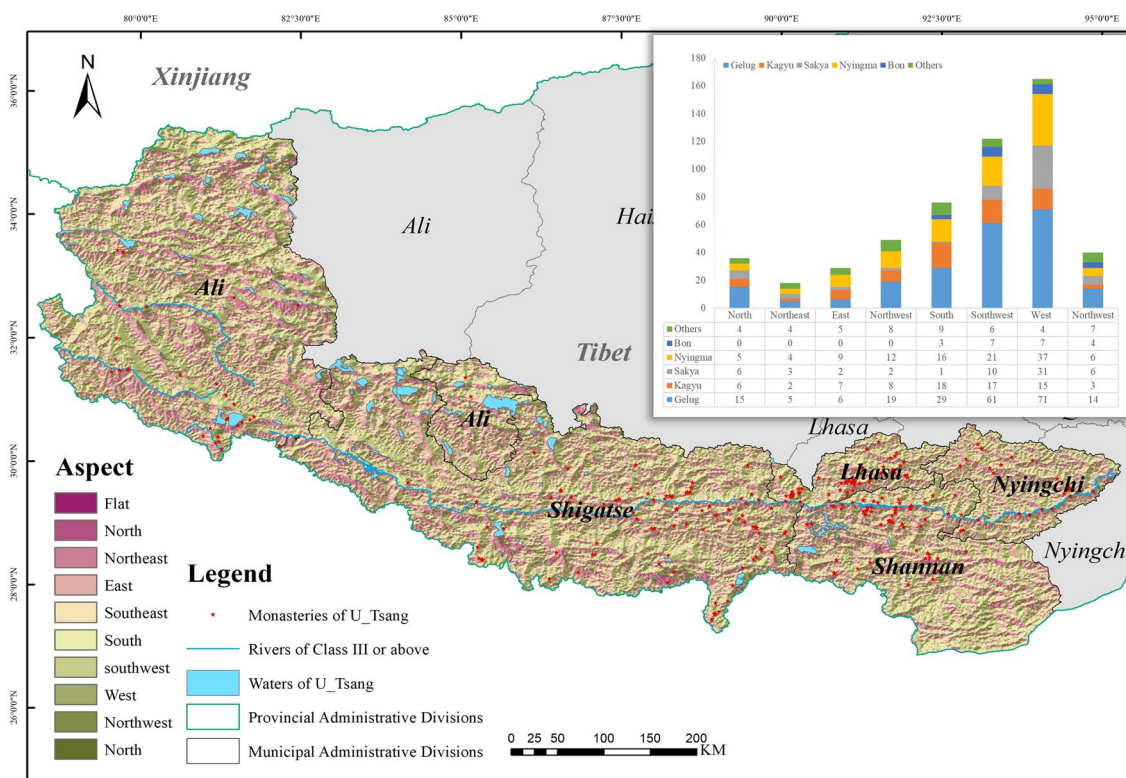


Fig. 10 Analysis of the impact of orientation on the distribution of monasteries

Table 5 Statistics of monasteries at different distances from the river

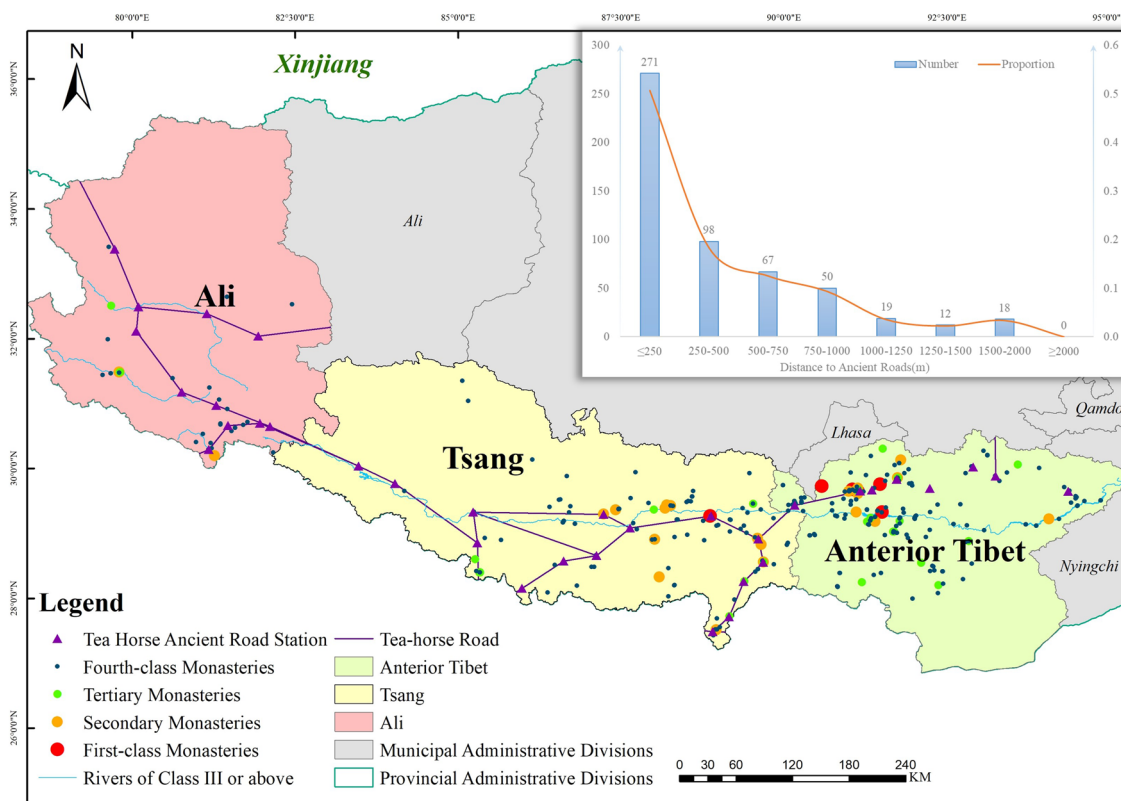
Distance to rivers	< 250	250~500	500~750	750~1000	1000~1500	1500~2000	> 2000
Number of monasteries	307	104	53	40	20	11	0
Monastery Proportion	0.574	0.194	0.099	0.075	0.037	0.021	0

to rivers corresponds to a higher number of monasteries. As the distance to rivers increases, the number of monasteries gradually decreases. For instance, there are only 11 monasteries within the range of 1.5 to 2 km from rivers, and there are no monasteries situated beyond 2 km. It indicates that an increase in the distance to rivers raises the challenges and costs of survival for monastery monks that discouraging them from establishing monasteries in areas farther away from rivers.

**Humanistic factors selection**

In addition to the significant impact of the natural geographical environment on the location, establishment, and scale of Tibetan Buddhist monasteries, the importance of socio-cultural factors in the development and diffusion of these monasteries can't be ignored. Therefore, we selected the Ancient Tea Horse Road as a representative ancient route to analyze the distribution of monasteries at different distances along this road. Population distribution was chosen as a measure of the influence of monastery presence on local religious activities.

(1) *Tea Horse Ancient Road* The Sino-Tibetan tea and horse trade began in the Tang Dynasty and continued until in the Qing Dynasty which went through several dynasties. The Tibetans who residing in the western regions of China considered tea as an indispensable necessity for their diet, stating, 'the fishy meat can't be digested without tea, the heat of highland barley can't be dispelled without tea.' However, due to the challenges of cultivating tea in the Tibetan Plateau where they lived. Tibetans established a trade route to import tea from neighboring regions such as Sichuan and Yunnan. This route primarily focused on tea commerce and became known as the 'Tea Horse Ancient Road.' The 'Tea Horse Ancient Road' is regarded as a corridor for economic and cultural exchange among ethnic groups in southwest China. It is an important road to strengthen ethnic exchanges, promote border economic development and maintain ethnic unity. This paper is based on the foundational data provided by Wang Xiao-hong [69]. The data were overlaid with the distribution of various levels of monasteries, as shown in Fig. 11. The analysis reveals that there is a relatively high concentration of first and second-level monasteries near the Tea Horse Ancient Road in Anterior Tibet, and fourth-level monasteries tend to cluster around the post stations along the ancient route. In Anterior Tibet, third-level monaster-



**Fig. 11** Analysis of the impact of distance from the Tea-Horse Ancient Road on the monastery distributions

ies are mainly concentrated in the southern part of Shannan and Lhasa with less spatial correlation with the Tea Horse Ancient Road. This discrepancy may be related to the fact that the ancient route in the historical period is incompletable. The distribution of monasteries in Tsang and Ali largely aligns with the route of the Tea Horse Road. Particularly in Tsang, the first three level monasteries are positioned in close proximity to the locations of the post stations along the Tea Horse Ancient Road. The spatial correlation between fourth-level monasteries and the Tea Horse Ancient Road is more pronounced in these two regions. Many fourth-level monasteries in Ali situated along the ancient road, while in the Tsang region they are concentrated around the post stations. By reclassifying the distance to the Tea Horse Ancient Road into eight categories and then conducting the zonal analysis. It can be observed from Fig. 11 that Tibetan Buddhist monasteries tend to be situated within the range of 250 m from the ancient road. The research results show that there are more Tibetan Buddhist monasteries located in areas with convenient transportation and frequent trade exchanges, indicating a positive correlation between transportation convenience and monastery distribution. It is of great significance for various aspects such as monastery environment, cultural dissemination, and human activities.

(2) *Population* The establishment of Tibetan Buddhist monasteries is naturally inseparable from the geographical environment and human activities. However, availability of ancient Chinese population data is currently one of the challenging issues in historical geography. The historical population in Tibetan areas of China is more controversial than that in other areas. Tibetan region has a history of multiple regime changes. At the same time, Tibetans did not pay taxes to the central court on a regular basis like ethnic groups in the Central Plains. Consequently, the Chinese government did not thoroughly investigate the exact population of Tibetans until the late twentieth century. Accurate historical population data for Tibetan regions are currently unavailable through effective channels. In addition, after the establishment of the autonomous region in Tibet, there were many policy implementations involving changes in the boundaries of administrative divisions from 1956 to 1986, including addition, cancellation and restoration. It was not until the early 1990s that the administrative boundaries of the U-Tsang region gradually stabilized. Therefore, in order to take into account the problems of subsequent analysis and boundary unification when selecting population data, this article uses the Tibetan population data of 1990. This study analyzes the distribution of Tibetan Buddhist monasteries based on 1990 population data [70], as shown in Fig. 11.

Population analysis results reveal a positive correlation between the distribution of monasteries in Anterior Tibet and Tsang which means that monasteries are more concentrated in areas with denser populations. The Ali area has a relatively complex and harsh terrain and a small population, but it still maintains a considerable number of monasteries. This may be related to the frequent regime changes in the region's history and the religious radiation of surrounding countries. Additionally, this suggests that although population density has a significant impact on the distribution of monasteries. But in regions with complex historical environments, the limiting factor of population can be overcome when the combined effect of other factors is strong.

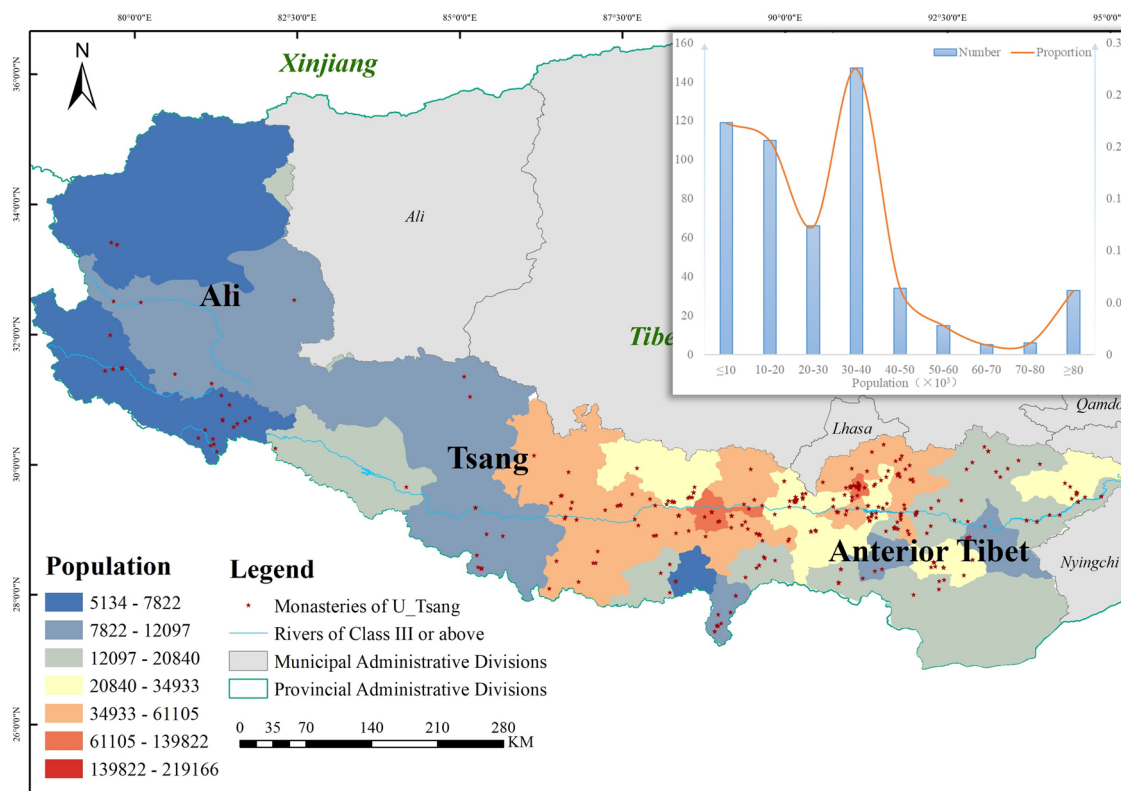
This study conducts zonal statistics of the population distribution in various counties and districts based on the eight levels (Fig. 12). The results indicate that under certain conditions, the number of people is proportional to the number of Tibetan Buddhist monasteries. Monasteries in U-Tsang region are generally distributed in multiple areas with population below 20,000, resulting in the largest number of monasteries in this population range. It can be seen that population is not the decisive factor affecting the number of monasteries when overcoming geographical spatial constraints. Areas with populations ranging from 20,000 to 30,000 have the fewest monasteries, while the general population in areas where most monasteries are established is 30,000 to 40,000. Regions with populations between 40,000 and 80,000 are less common, resulting in a smaller number of monasteries. The only area with a population of more than 80,000 is Lhasa which has important religious significance and political status in U-Tsang and even the entire Tibet region. Under the dual gravity of religion and politics, many sects established their monasteries here, so the number of monasteries in this area is second to none in U-Tsang.

#### **Detection of main influencing factors**

(1) *Detection of main influencing factors on the distribution of monasteries* This research utilized the factor detection module in geodetector to quantitatively analyze six factors that affect the distribution of monasteries in U-Tsang, including elevation, slope, monastery orientation, distance to rivers, distance to the ancient road, and population density. Aim to explore the role of various natural factors or human factors in explaining the spatial differences in the monastery distribution, the q value calculated by the geodetector can be used to explain the significance of each factor. The main results of factor detection are presented in Table 6.

The research results show that the explanatory power of various factors affecting the monastery distribution





**Fig. 12** Analysis of the impact of population factors on the monastery distribution

**Table 6** Detection results of main factors affecting the distribution of monasteries

Dependent variable	Interfering factor	q-value (%)
X1	Elevation	8.30
X2	Slope	1.20
X3	Monastery orientation	6.70
X4	Distance to rivers	7.40
X5	Distance to road	8.80
X6	Population density	19.0

in U-Tsang area from high to low is: population density > distance to the Tea Horse Ancient Road > elevation > distance to rivers > monastery orientation > slope. Analyzing from the explanatory power (q) of each influencing factor, the impact of population density is much higher than that of other factors. This shows that the establishment of Tibetan Buddhist monasteries is inextricably linked to the Tibetan Buddhist believers. Population density has greatly affected the incense of Tibetan Buddhist monasteries in U-Tsang. Apart from population density, the factors with relatively close q-values are the distance to the Tea Horse Ancient

Road and elevation, and the former has slightly higher explanatory power than elevation. This implies that Tibetan Buddhist monasteries in U-Tsang are significantly influenced by a series of socio-economic activities primarily conducted along the Tea Horse Ancient Road. In addition to the fact that the development of religion in Tibetan areas is not only dependent on the economy, but also relate to the construction of major ancient roads such as the Tea Horse Road which promoted religious and cultural exchanges between Tibetan areas and the Central Plains, India, and other regions. The explanatory power of slope is the smallest that shows the influence of slope on the monastery establishment is relatively weak.

(2) *Interaction of factors influencing the spatial distribution of monasteries* The establishment of religious spaces is often influenced not solely by individual factors but rather shaped by the combined effects of multiple factors, creating the distribution pattern of Tibetan Buddhist monasteries in U-Tsang. After exploring the main influencing factors of monastery distribution, this study utilized the factor interaction detector module of geodetector to analyze the interaction of various influencing factors (Table 7).

**Table 7** Detection results of dual-factor

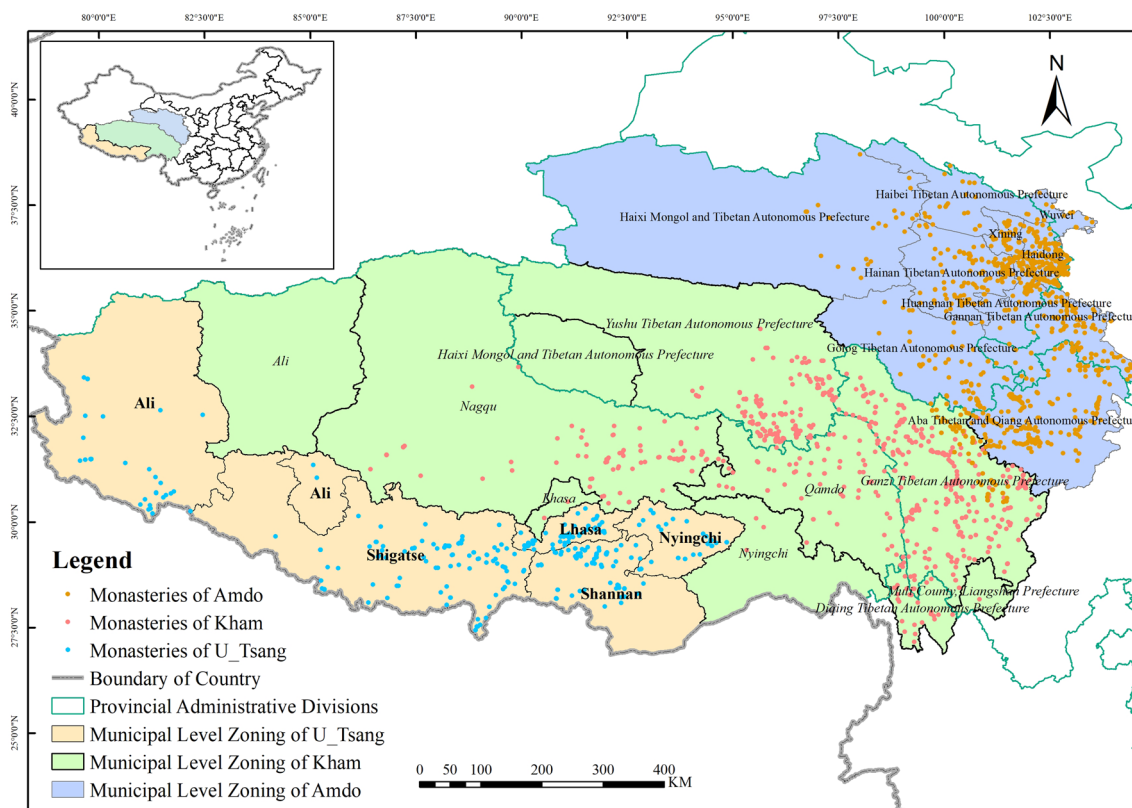
Dual-factor	Explanatory power	Interactive results
Elevation / slope	0.252	Enhance
Elevation / monastery orientation	0.215	Enhance
Elevation / distance to rivers	0.353	Enhance
Elevation / distance to the Ancient Road	0.344	Enhance
Elevation / population density	0.391	Enhance
Slope / monastery orientation	0.138	Weaker-Enhance
Slope / distance to rivers	0.379	Enhance
Slope / distance to the Ancient Road	0.268	Enhance
Slope / population density	0.312	Enhance
Monastery orientation / distance to rivers	0.378	Enhance
Monastery orientation / distance to the Ancient Road	0.199	Weaker-Enhance
Monastery orientation / population density	0.407	Stronger-Enhance
Distance to rivers / distance to the Ancient Road	0.313	Enhance
Distance to rivers / population density	0.572	Stronger-Enhance
Distance to the Ancient Road / population density	0.520	Stronger-Enhance

According to the results of the dual-factor detection, the interaction between various influencing factors is greater than the sum of the individual factors in U-Tsang. The results (Table 7) indicate that the dual-factor explanatory power of distance to the rivers and population density is as high as 0.572 which suggest that the interaction between these two factors has a significantly enhancing effect. This outcome highlights the crucial impact of population density in the monastery establishment. On the other hand, the interaction between slope and monastery orientation exhibits the weakest non-linear enhancement. It indicates that the monastery establishment in the U-Tsang region relies not only on the influence of natural factors but also significantly on the impact of humanistic factors.

Through the interaction analysis between dual factors, it is evident that the interaction with population density enhances the influence of various factors significantly. However, the interaction with slope is not as strong as the interaction between slope and distance to the rivers. This proves from the side that although population density is the major influencing factor of the monastery distribution, it is not the decisive factor. The difficulty of obtaining necessary resources that affects the production activities of Tibetan Buddhist monks and believers also plays a very important role in the selection of monastery locations. It also shows that the enhanced effect produced by the interaction between multiple factors can offset the main influence of a single factor under certain conditions.

### Comparison of three major Tibetan regions

To deepen our understanding of the spatial differentiation characteristics of Tibetan Buddhist monasteries in Amdo, Kham, and U-Tsang regions, we conducted a comparative analysis and visualized the distribution features within these three major traditional Tibetan geographical units. From the Fig. 13, it is evident that Tibetan Buddhist monasteries in the Amdo region are widely distributed but not evenly, with most monasteries concentrated in the eastern and southern parts. The geographical scope of Kham Tibetan area is the largest among the three major Tibetan areas, but the distribution of monasteries is not throughout the entire territory. Despite being the smallest in terms of area among the three regions, U-Tsang region has a more uniform distribution of monasteries compared to the other two. The distribution trends of monasteries in the three regions are closely related to the flow direction of major rivers within each region. For instance, the monasteries in Amdo Tibetan area show obvious clustering along Huangshui River and the upper reaches of Yellow River. In Kham region, the distribution of monasteries is closely related to the flow direction of Lancang River and Jinsha River within the territory. In U-Tsang region, the distribution of Tibetan Buddhist monasteries is consistent with the flow direction of Brahmaputra River that runs through the entire territory. It indicates that the distribution of major river systems in various Tibetan areas has greatly affected the location and establishment of Tibetan Buddhist monasteries in these areas.



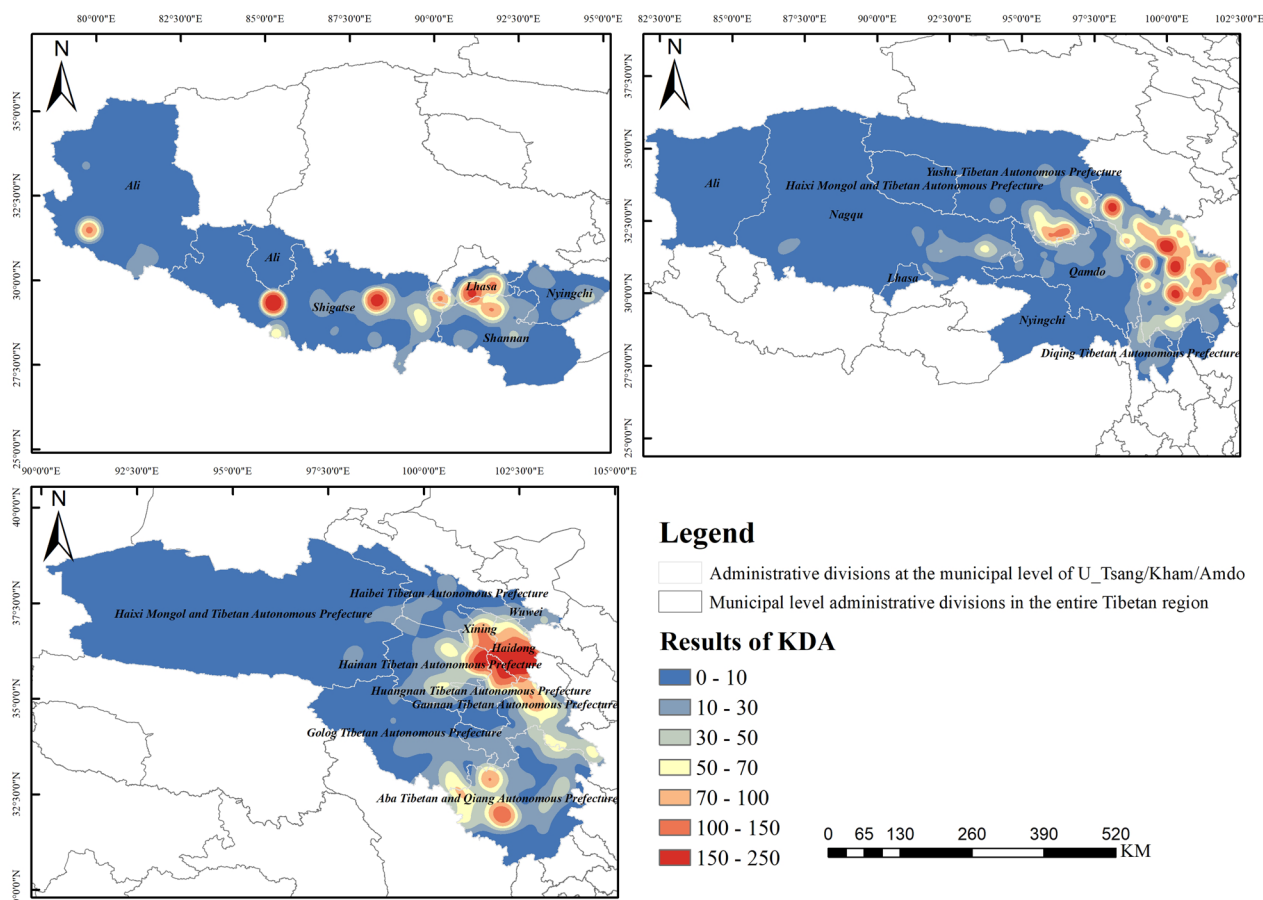
**Fig. 13** Spatial distribution of Tibetan Buddhist monasteries in three major Tibetan

In order to better summarize and compare the distribution characteristics of monasteries in the three major Tibetan areas, we conducted kernel density analysis (Fig. 14). The results indicate that there is a significant clustering in monasteries across all three regions, but the distribution patterns vary. Through an in-depth review of the historical context, we found that the main causes of the spatial differentiation of religions in the three major Tibetan areas are closely related to the political attitude of the ruling regime. U-Tsang region served as the historical seat of power in Tibet, with Lhasa in Anterior region serving as the political core. Lhasa is being both the political center and the holy place of religious pilgrimage. The rulers adopting policies favoring religious affairs which resulting in the concentration of various sects of Tibetan Buddhism in the Anterior Tibet region, forming a major core centered around Lhasa. Subsequent shifts in religious power dynamics that influenced by political events such as the anti-Buddhist campaigns and the revival of Buddhism led to the spread of Tibetan Buddhism to more distant regions like Amdo and Kham far away from U-Tsang. The Kham Tibetan area was the area where Vairochana taught in the early days and had a good foundation for the spread of Buddhism. It later

received a significant number of refugee monks from U-Tsang. A large number of Buddhist monasteries were established along the ‘Ancient Tea Horse Road,’ an economic and cultural hub connecting Yunnan, Tibet, and Sichuan, for proselytizing and propagating the Tibetan Buddhism. Contributing to the rapid development of Tibetan Buddhism in this region. Amdo held importance as a borderland on the Sino-Tibetan border since the Yuan Dynasty. It has important military strategic significance and received great attention from the court during the Ming and Qing Dynasties. As an essential tool for the imperial court to stabilize the region, Tibetan Buddhism flourished in Amdo Tibetan area with numerous monasteries established in the eastern areas.

**Conclusion**

Utilizing GIS analysis methods, the study explores the spatial distribution patterns of Tibetan Buddhist monasteries in Tibetan region. Subsequently, factor analysis is employed to qualitatively and quantitatively analyze the factors influencing the spatial distribution of Tibetan Buddhist monasteries. Additionally, historical factors are considered in the analysis of the monasteries. The main conclusions are as follows:



**Fig. 14** Density analysis results of monasteries in three major Tibetan areas

1) The birth and development of monastery clusters in different regions are closely linked to changes in local political power at different times, and the spatial pattern of religious sites is deeply influenced by fluctuations in political power. The evolution of Tibetan Buddhist monasteries in U-Tsang region is inherently linked to the direct influence of the political system in the distribution of power in this area. The political structure in U-Tsang region directly influences the spatial distribution of Tibetan Buddhist monasteries through the specific medium of the followers, emerging as one of the most direct and evident factors shaping the spatial distribution of Tibetan Buddhism in this area. The distribution of monasteries in U-Tsang region exhibits notable spatial variations, with distinct distributions in the three sub-regions. Higher-influence monasteries are predominantly situated in Anterior Tibet and Tsang, the political core, forming multiple high-density aggregation centers, reflecting the close relationship between monastery distribution and the location of political power. This

illustrates that the location of political power in the Chinese Tibetan region plays a crucial role in shaping the geographical spatial pattern of religion. However, the fluctuation of political power under different historical backgrounds directs the development of religions aligned with that power.

2) The spatial distribution of Tibetan Buddhist monasteries is the result of a complex interplay between natural environmental factors and historical-cultural factors. In U-Tsang region, monasteries tend to be distributed at elevations between 3000–5000 m, on gentle slopes facing west, and in proximity to rivers and roads. The number of monasteries correlates positively with population density, but population density alone is not the decisive factor. The impact of population density on the location of monasteries is significantly higher than that of other influencing factors. Interaction analysis of dual factors indicates that the interaction between distance to rivers and population density has a more pronounced effect on monastery distribution than other factors. The results

suggest that the spatial arrangement of religious sites is an inevitable outcome of the interaction between human activities and the environment.

- 3) The religious spatial distribution in the three major Tibetan regions exhibits significant spatial variations, which are related to the unique geographical environments and historical backgrounds of each region. In U-Tsang region, Tibetan Buddhist monasteries are primarily clustered in a point-like pattern, concentrated in Anterior Tibet and Tsang regions. This is associated with the flourishing religious development in U-Tsang region. In Kham region, monasteries follow an interwoven pattern of point-like and belt-like distributions, forming multiple high-density aggregation centers in the eastern part of Kham-Tibet region. This is due to the accessibility of the 'Tea Horse Ancient Road' in Kham region, facilitating frequent cultural and economic exchanges among different ethnic groups. In Amdo region, monasteries are mainly distributed in the eastern part. This can be attributed to the historical military dispatches and protection by successive central governments in Amdo region.

The methods employed in this study are relatively conventional, and their innovativeness still requires further refinement. In subsequent research, we plan to integrate relevant models and formulas to propose more optimized quantitative analysis methods. Due to space limitations, this paper did not delve into a thorough qualitative exploration and quantitative analysis of the crucial human factor—political factors—that significantly influence the religious distribution pattern. In the future research should address these limitations, aiming for a more comprehensive and in-depth understanding of the impact of political factors on the distribution of religion.

#### Author contributions

Conceptualization, S.F.; Y.Z.; X.L. and Y.Y.; methodology, S.F. and Y.Z.; software, S.F.; data collection, S.F. and X.L.; validation, S.F.; Y.Z.; formal analysis and investigation, S.F. and Y.Y.; writing—original draft preparation, review and editing, S.F.; Y.Z.; funding acquisition, Y.Z.; All authors have read and agreed to the published version of the manuscript.

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#### Data availability

The datasets generated and analyzed during the current study are not publicly available due to the involvement of religious confidentiality but are available from the corresponding author on reasonable request.

## Declarations

#### Competing interests

The authors have no conflicts of interest to declare that are relevant to the content of this article.

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