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Identifying the spatial differentiation factors of traditional villages in China

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Abstract

China's agricultural civilization had left numerous traditional villages (TVs) containing rich historical information and cultural landscape. Exploration the spatial agglomeration characteristics of TVs and their influencing factors is essential for the sustainable development, utilization, and protection of TVs in China. However, previous studies lacked a comprehensive analysis of the spatial distribution of TVs and their driving factors, especially at the national scale. To fill this gap, this study analyzed the spatial agglomeration characteristics and influencing factors of five batches of TVs in China during 2012–2019. The results show that TVs in China were mainly located east of the Hu Line, that is, in the southern and eastern regions of China. The spatial distribution of TVs had significant clustering characteristics, and the gravity center was mainly distributed in central China, and the compactness of the spatial distribution of TVs increased from the first to the fifth batches. The TVs were mainly located at low elevations, northern slope aspect, warm and humid areas. Ferralisol and cultivated vegetation were the main soil and vegetation types in most TVs. TVs tended to be more numerous in the vicinity of low economic development levels, low population density, and rivers. In addition, TVs had a significant correlation with intangible cultural heritage. The results of this study could provide scientific guidance for heritage protection and sustainable development of TVs.

Keywords Traditional villages, Spatial agglomeration, Spatial autocorrelation, Influencing factors, China

Introduction

As a carrier of history, the preservation of traditional villages (TVs) is facing great challenges worldwide [1]. Carrying the agricultural civilization of the Chinese nation for thousands of years, Chinese TVs are rich in cultural connotations and are of precious historical value [2, 3]. However, with the rapid urbanization, the protection of TVs is under great pressure [4]. The disappearance of traditional agricultural production and way of life, agricultural culture, folk customs, and characteristic residential areas poses a serious threat to the realization of the great rejuvenation of the Chinese nation. To address this situation, from 2012 to 2019, five batches of TVs have been listed on the Chinese Traditional Village List (CTVL) by the Chinese government [4]. This has also triggered a boom in academic studies on the spatial distribution characteristics of TVs.

Researches on TVs can be traced back to the early 1990s, such as the value and culture of TVs [5–10], integrity protection [11, 12], development and utilization methods [9, 10], spatial distribution characteristics [12–19], dynamic mechanisms [20–22], tourist exploitation [23–25], landscape analysis [26, 27], the models of

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development and evolution [28–33], update and reconstruction [34, 35], and the climatic characteristics of its location [36–38]. Previous studies have also analyzed the ecosystem and the corresponding sustainable development of TVs [18, 19, 39]. In terms of methods, the studies of Chinese TVs have gradually transformed from qualitative description, case study, and comparative study to quantitative analysis. Among them, the exploration of the spatiotemporal distribution pattern characteristics and spatial differentiation factors of TVs combined with GIS technology has gradually become mainstream [4, 14]. For research areas, case studies of TVs are more common [40, 41]. However, previous studies have mostly focused on the regional scale, while the spatiotemporal patterns of TVs at the national scale are still unclear.

Previous literature has made great methodological contributions, including the use of kernel density estimates, geographic concentration indices, standard deviation ellipses, and a host of other methods of spatial analysis or mathematical statistics [14]. The analysis methods of spatial differentiation factors of TVs mainly adopted qualitative analysis, GeoDetector, geographically weighted regression models, and other methods [5, 21]. Geostatistical analysis, as a simple and accurate objective method, is still relatively little used to reveal the spatial differentiation factors of TVs. The distribution of TVs was closely related to topography and climate, which restricted the production and living activities of the public, as well as the location of TVs [5]. In terms of socioeconomic factors, the development of the socioeconomic elements affected the evolution of TVs. For example, the development of urbanization will lead to the extinction of a large number of TVs. Besides, the population density, urbanization level, traffic accessibility level, and economic development level of the areas where the TVs were located were lower than in other regions. Therefore, when analyzing the spatial differentiation factors of TVs, the natural-, social-, economic-, and historical factors should be taken into account.

Thus, previous scholars have mostly focused on case studies of TVs or analyzed the spatial patterns and spatial differentiation factors of some TVs from a regional perspective. They also provide a methodological and theoretical basis for studying the spatial characteristics and spatial differentiation factors of TVs. Currently, China has announced five batches of TVs, and few studies explore the spatial agglomeration characteristics and influencing factors of all batches of TVs. Especially, studies that analyze the spatial clustering characteristics and drivers of TVs on a large scale, such as the national scale, are rare. Furthermore, the use of geostatistical analysis to analyze the factors influencing the spatial distribution of TVs can avoid bias in the fitting effect of spatial regression models and provide more objective results.

Five thousand years of China's agricultural civilization have left behind excellent cultural heritage and numerous TVs, providing a suitable case study area. Previous studies have failed to analyze the spatial characteristics of these five batches of TVs and their influencing factors at the national level, which restricts policymakers from formulating development and protection measures for TVs at the macro level. Therefore, it is necessary to study the spatial characteristics and influencing factors of Chinese TVs. Here, we attempted to adopt a series of spatial analyses to reveal the spatial agglomeration characteristics and its drivers of five batches of TVs in China. This study can inform decision-making on issues facing rural China, such as current hollowing out, inappropriate construction and development, rural conservation, and urban–rural development.

Data sources

The CTVL includes five batches of TVs in 2012 (646), 2013 (915), 2014 (994), 2016 (1598), and 2019 (2666). The spatial distribution data of the five batches of TVs were obtained from the Global Change Scientific Research Data Publishing System (http://geodoi.ac.cn/WebCn/Default.aspx) [43]. By village names or geometric centers, this study extracts the coordinate locations of TVs from Google Maps or Baidu Maps. If a traditional village could not be found by the above method, we used the geographical coordinates of the administrative district at the superior level instead. For unconventional and difficult-to-identify village names, confirmation measures such as asking for relevant information or contacting the village directly were taken to determine the name and coordinates of the village. The selected factors and their data sources and data formats are shown in Table 1.

Methods

Standard deviation elliptic analysis

As a common method to measure the distribution characteristics of spatial points, the main results of standard deviation ellipse analysis include the mean center, long axis, short axis, and ellipse direction. The mean center characterizes where the center of gravity of the regional traditional village distribution is located. The long axis characterizes the direction of traditional village distribution, and the short semi-axis characterizes the extent of traditional village distribution. If the long axis and the short axis are closer, the greater the dispersion of traditional village distribution and the less obvious the spatial agglomeration, and vice versa. This study employed the standard deviation ellipse to analyze the spatial

Table 1 Data sources of each factor

Variables	Data sources	Data format
Elevation	RESDC (http://www.resdc.cn)	GeoTIFF (1000 m-resolution)
Slope direction	RESDC (http://www.resdc.cn)	GeoTIFF (1000 m-resolution)
Average annual temperature	RESDC (http://www.resdc.cn)	GeoTIFF (1000 m-resolution)
Annual precipitation	RESDC (http://www.resdc.cn)	GeoTIFF (1000 m-resolution)
Vegetation types	RESDC (http://www.resdc.cn)	GeoTIFF (1000 m-resolution)
GDP	RESDC (http://www.resdc.cn)	GeoTIFF (1000 m-resolution)
Population	World pop project (https://www.worldpop.org)	GeoTIFF (1000 m-resolution)
River	National Geomatics Center of China (http://ngcc.sbsm.gov.cn)	Shipfile
Road	National Geomatics Center of China (http://ngcc.sbsm.gov.cn)	Shipfile
National intangible cultural heritages	Global Change Research Data Publishing & Repository (https://www.geodoi.ac.cn)	Shipfile

RESDC: Data Center for Resources and Environment, Chinese Academy of Sciences. Road: Including railway, national highway, expressway, and other traffic data

characteristics of the five batches of TVs in China. The equations are as follows:

$$\overline{X}_w = \sum_{i=1}^{n} w_i x_i \bigg/ \sum_{i=1}^{n} w_i \tag{1}$$

$$\overline{Y}_w = \sum_{i=1}^{n} w_i y_i \bigg/ \sum_{i=1}^{n} w_i \tag{2}$$

$$\theta = \arctan\left[\left(\sum_{i=1}^{n} x_i'^2 - \sum_{i=1}^{n} y_i'^2\right) + \sqrt{\left(\sum_{i=1}^{n} x_i'^2 - \sum_{i=1}^{n} y_i'^2\right)^2 + 4\left(\sum_{i=1}^{n} x_i\prime y_i\prime\right)^2}\right] \bigg/ 2\sum_{i=1}^{n} x_i\prime y_i\prime \tag{3}$$

$$\delta_x = \sqrt{\sum_{i=1}^{n} \left(x_i\prime \cos\theta - y_i\prime \sin\theta\right)^2 \bigg/ n}, \delta_y = \sqrt{\sum_{i=1}^{n} \left(x_i\prime \sin\theta - y_i\prime \cos\theta\right)^2 \bigg/ n} \tag{4}$$

where $(\overline{X}_w, \overline{Y}_w)$ indicates the average center coordinates; θ is the azimuth angle;

(x_i, y_i) indicates the geometric center coordinates of county unit i; w_i is the weight; δ_x and δ_y indicate the standard deviation along the major axis and minor axis, respectively. The standard deviation ellipse is mainly achieved by ArcGIS 10.3 (Spatial Statistics Tools/ Measuring Geographic Distributions /Directional Distribution).

Spatial autocorrelation analysis

Global Moran's I is the spatial characterization of spatial object attribute values throughout the area, which is commonly employed to detect spatial differences caused by spatial dependencies [44]. In this study, we performed spatial autocorrelation analysis to explore the characteristics and size of the spatial clustering of TVs at multiscales (e.g., province-, prefecture-, county-, township-, grid-level). The equation is defined as:

$$I = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} wij(xi - \overline{x}) \cdot (xj - \overline{x})}{S^2 \sum_{i=1}^{n} \sum_{j=1}^{n} wij} \tag{5}$$

where, n is the number of samples; S^2 is the variance of samples; x_i and x_j indicate the attribute values of the spatial unit i and j, respectively; $\overline{x}$ is the mean of the attribute values; w_{ij} is the spatial weights matrix.

Geostatistical analysis

In this study, we introduced various functions of ArcGIS, including overlay analysis, buffer analysis, statistical analysis, and intersection analysis [45]. Specifically, we use superposition analysis to investigate the spatial distribution of TVs regarding elevation, slope aspect, soil types, and vegetation types. Buffer analysis was used to study the spatial distribution of TVs along rivers and roads. In addition, we used spatial statistical analysis to analyze the relationship between TVs and population, economy, history, and culture.

Results and analysis

Spatial distribution characteristics of traditional villages in China

General distribution rule

The top 3 provinces in terms of the number of TVs in each batch are shown in Table 2. It can be seen that in the first batch, Guizhou, Yunnan, Fujian, and Shanxi had the largest number of TVs. In the second and third batches, Yunnan had the largest number of TVs. In the fourth batch, Zhejiang had the most TVs, Hunan was the second and Shanxi was the third. In the fifth batch, Hunan had the most TVs. Overall in the five batches, the province with the most TVs was Guizhou Province, followed by Yunnan Province, and thirdly Hunan Province. On the contrary, there were fewer TVs in the northeast (e.g., Jilin, Liaoning) and northwest (e.g., Ningxia Hui Autonomous Region, Xinjiang Uygur Autonomous Region) regions. Overall, Xinjiang Uygur Autonomous Region, Shanghai, and Tianjin had the fewest TVs, only 4.

Regional distribution rule

Judging from the distribution characteristics of three major regions in China, there were 2550, 2387, and 1882 TVs in the western, central, and eastern regions of China, respectively. The spatial distribution showed a decreasing trend from west to east. From the characteristics of north–south distribution, the TVs in China were higher in the south than in the north. There were 4892 TVs in the south, while there were only 1927 TVs in the north. The spatial distribution characteristics of five batches of TVs were the same, mainly distributed on the right side of the Hu Line and concentrated in East China and Southwest China (Fig. 1), which were consistent with Chinese population distribution characteristics. Generally, it could be found that the agglomeration areas of Chinese TVs were mainly distributed in southeast Guizhou to west Hunan, southern Anhui to west Zhejiang to northwest Fujian, Shanxi, Hebei, Henan, and northwest Yunnan.

In the nine major agricultural divisions (Fig. 2a), the density of TVs there reached more than 2.479 TVs/ km^2 in the middle and lower reaches of the Yangtze River, with the highest degree of aggregation. This was followed

Table 2 The top three provinces in the number of traditional villages in each batch

	First batch	Second batch	Third batch	Fourth batch	Fifth batch	Five batches
Top 1	Guizhou (88)	Yunnan (232)	Yunnan (208)	Zhejiang (225)	Hunan (401)	Guizhou (723)
Top 2	Yunnan (62)	Guizhou (202)	Guizhou (135)	Hunan (166)	Shanxi (271)	Yunnan (708)
Top 3	Fujian and Shanxi (48)	Jiangxi (56)	Zhejiang (86)	Shanxi (150)	Fujian (265)	Hunan (658)

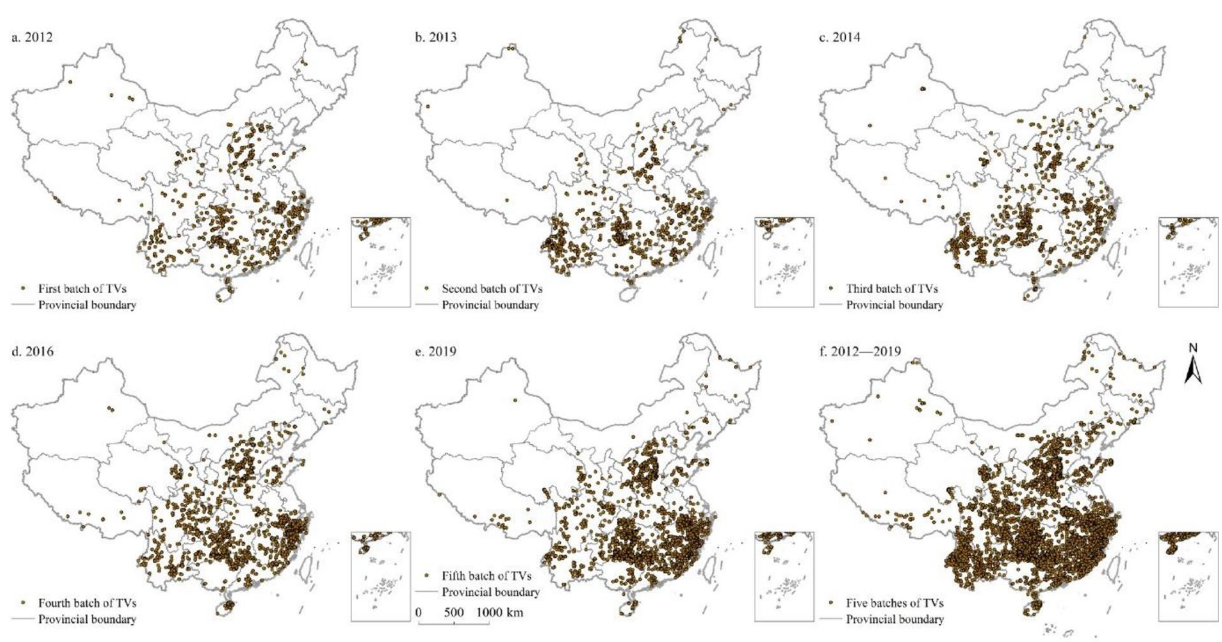

Fig.1 Spatial distribution of traditional villages in China

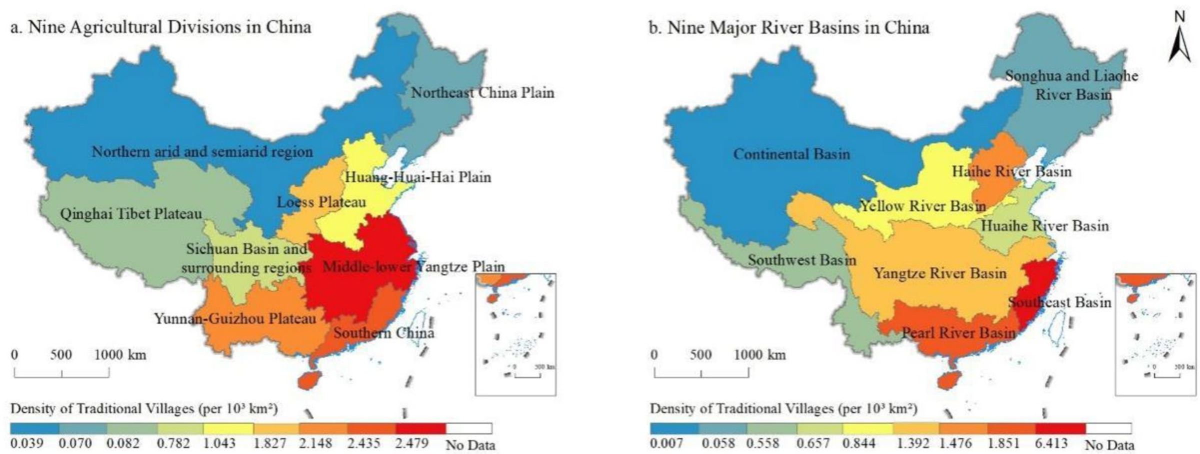

Fig.2 Traditional villages density in nine agricultural divisions and nine drainage basins in China

by the higher density of TVs in South China, the Yunnan-Guizhou Plateau and the Loess Plateau. However, the density of TVs in the Huang-Huai-Hai Plain, Sichuan Basin, Qinghai–Tibet Plateau, Northeast China Plain, and arid and semi-arid regions in North China was relatively low. In the nine major river basin areas (Fig. 2b), the density of TVs in Southeast Basin, Pearl River Basin, Haihe River Basin, and Yangtze River Basin was relatively high, all reaching 1 traditional village/ 10^3 km^2. And the concentration of TVs in the Continental Basin and the Songhua River and Liao River basins is not high.

Center and distribution of Chinese traditional villages

The results of the standard deviation ellipse are shown in Table 3 and Fig. 3. The first to fifth batches of Chinese traditional village centers were located in Cili County in Hunan, Songtao Miao Autonomous County in Guizhou, Yongding District in Hunan, Zhijiang City in Hubei, and Huarong County in Hunan, respectively. The centers of all five batches of Chinese TVs were located in Linli County, Hunan Province. The above results indicate that the centers of Chinese TVs were mainly distributed in southeastern Guizhou, western Hunan, and western Hubei. The standard deviation ellipse analysis of TVs can reveal the directionality and compactness of TVs. The results showed that the elliptical direction of the five batches of TVs in China was stable in the northeast-southwest direction. Compared with the first batch of TVs, the semi-major axes of the second and third batches of TVs increased, but the semi-minor axis decreased, while the semi-minor axes and semi-major axes of the fourth and fifth batches of TVs decreased. The above indicated a more compact distribution of TVs.

Spatial agglomeration patterns of traditional villages in China

This study adopted the global autocorrelation Moran's I index to estimate the spatial agglomeration

Table 3 Parameters of standard deviation ellipse of the spatial distribution of traditional villages in China

Batches	Latitude and longitude of centers	Semi-major axis/km	Semi-minor axis/km	Azimuth angle
All Batches	29.538296°N 111.609262°E	899.296	722.949	65.785
Batch 1(2012.12)	29.518546°N 111.239994°E	880.610	777.266	59.670
Batch 2(2013.08)	28.053758°N 109.086609°E	982.859	614.002	69.197
Batch 3(2014.11)	29.335027°N 110.241361°E	1027.286	721.603	63.341
Batch 4(2016.12)	30.322941°N 111.880643°E	874.290	774.640	55.525
Batch 5(2019.06)	29.636757°N 112.904614°E	772.228	698.431	75.498

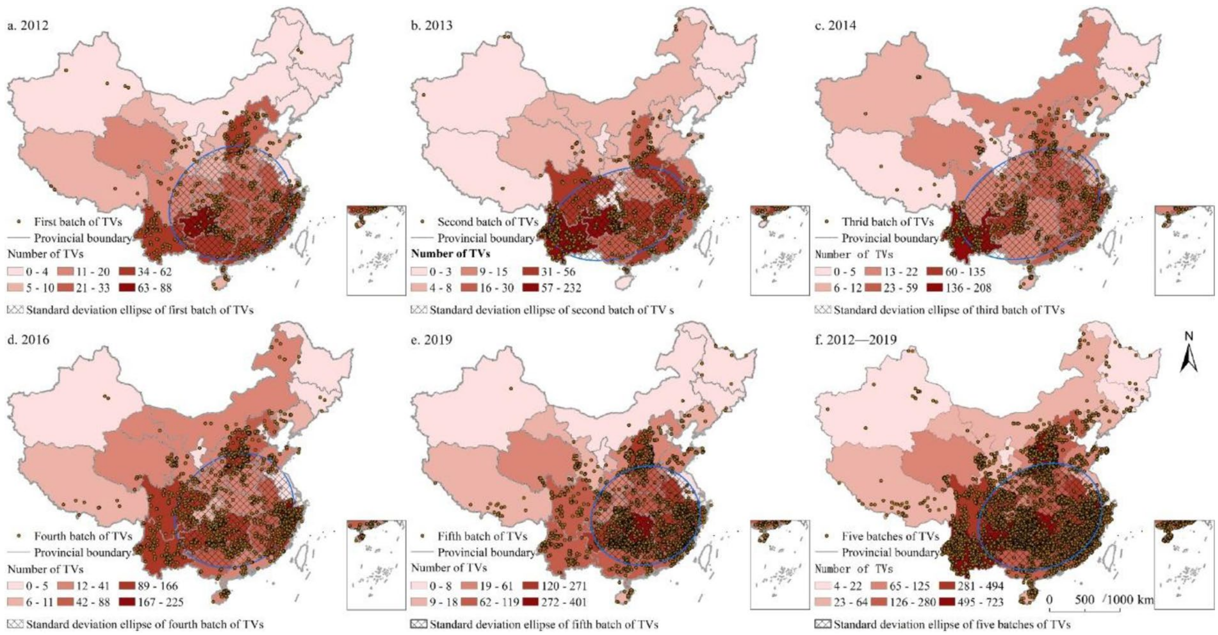

Fig. 3 Standard deviation ellipse of traditional villages in China

characteristics of TVs in China. Specifically, the global spatial autocorrelation analysis of the traditional village density values was performed on the provincial level, municipal level, county level, township level, and a grid unit of 100×100 km, respectively. The global autocorrelation Moran's *I* of TVs from the provincial level to the township level was 0.306, 0.304, 0.373, and 0.323, respectively. All these results were positive and significant at the level of 0.001, indicating that the spatial distribution of Chinese TVs has obvious spatial agglomeration trend. On the county level, the global autocorrelation Moran's *I* of TVs was the largest, while at 100×100 km grid scale, Moran's *I* was the smallest (Fig. 4).

Influencing factors of Chinese traditional villages

Terrain and landform

The geographical elements are important factors affecting the distribution of TVs. Under different terrain conditions, the number and density of Chinese TVs exhibited obvious spatial differentiation. This spatial differentiation was mainly manifested in the decreasing density and number of TVs as the elevation increased. The largest number of TVs was within an elevation of 0 ~ 200 m, accounting for 23% of the total number of TVs in China (Fig. 5a), indicating that TVs were mainly concentrated in low-elevation areas. Below the elevation of 1000 m, the traditional village's density was high, which reached 1 traditional village/10^3 km^2. With the increase in elevation, the number and density of TVs continued to decrease. According to the slope aspect (Fig. 5b), most of the TVs were located in areas with north, west, and northwest slope aspects. Especially, the northwest-facing areas had the largest distribution of TVs, accounting for about 18% of the total number of TVs. The areas located in the south-facing aspect had the least distribution of TVs, accounting for about 10% of the total. Overall, the TVs located on the northern slope were larger than those on the southern slope, which is in line with the Chinese tradition of "sitting in the north and facing south".

Climatic conditions

Appropriate climate conditions are conducive to the formation of TVs, and the number and density of TVs are different under different temperature and precipitation conditions. According to Fig. 5c, TVs were mainly distributed in areas with an annual rainfall of between 300 and 2500 mm, accounting for 97% of the number of TVs in China. Among them, the number of TVs in areas with annual rainfall between 400 and 500 mm was the largest. With the increase in annual rainfall, the density of TVs was increasing. The density of TVs in areas with annual rainfall between 2400 and 2500 mm was the largest and reached 0.477 TVs/10^3 km^2, indicating that the TVs were more likely to distribute in humid areas. With the increase in the annual average temperature, the number and density of TVs first increased and then decreased (Fig. 5d). The cumulative number of TVs in the region with an average annual temperature of 15–19 ℃ accounted for 51%, among which the number and density of TVs were the largest when the average annual

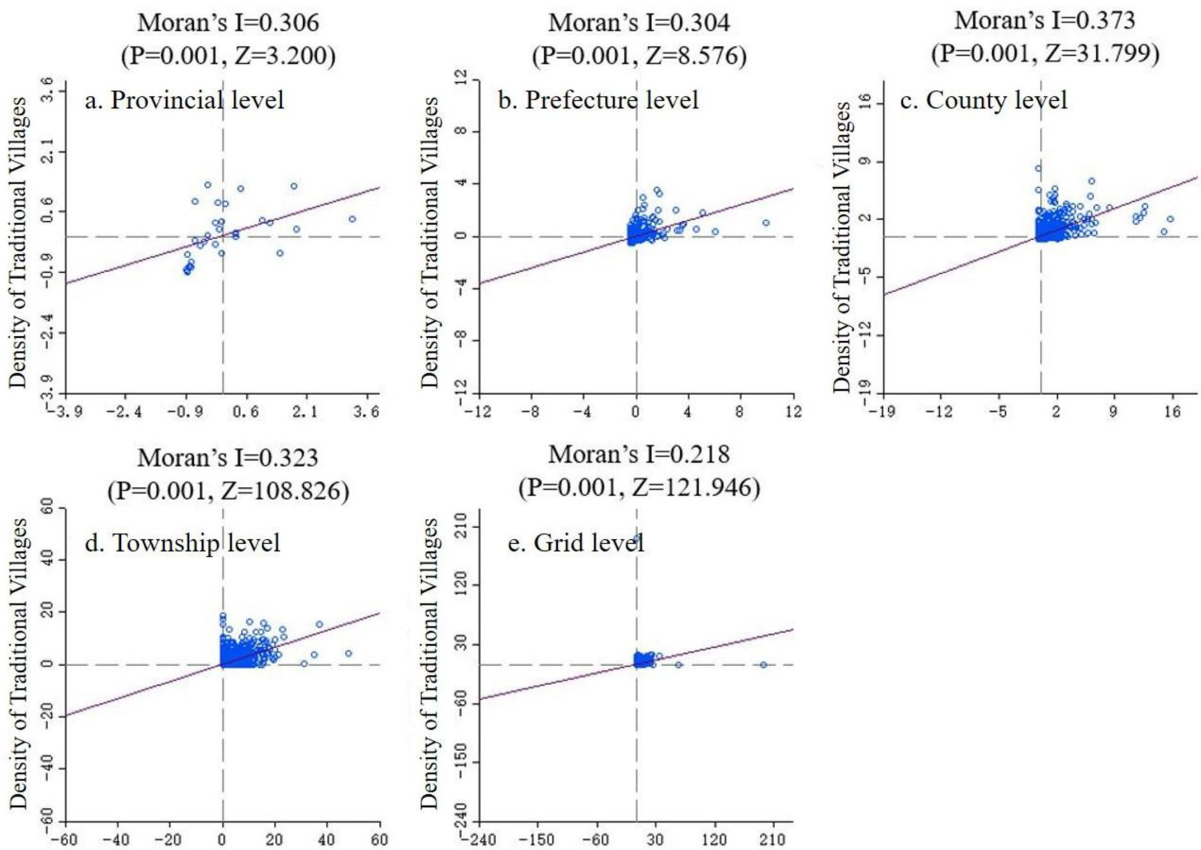

Fig. 4 Moran scatter plot of traditional villages density in China at different spatial scales

temperature of 17–18 ℃. The density of TVs in regions with an average annual temperature of 11–21 ℃ was all higher than 1.500 TVs/10^3 km^2.

Soil types

Soil characteristics can affect the size of land productivity and the farmers' production and lifestyles. Soil types had a certain influence on the distribution pattern of TVs. According to Table 4, the distribution of TVs varied evidently across different soil types. The number of TVs in the soil type area of ferralisols and anthrosols was the largest, accounting for 40% and 21% of the number of TVs in China, respectively. Among them, the density of TVs was the highest in the soil type area of anthrosols, reaching 3.025 TVs/10^3 km^2, followed by the density of ferralisols type area with 2.429 TVs/10^3 km^2. Secondly, the TVs were also more likely to distribute in the soil type area of anthrosols, primary soil, and semi-aching soil. The distribution of TVs in the areas of desert soil, saline-alkali soil, alpine soil, and other soil types was less, the degree of village agglomeration was low, and the density is less than 0.100 TVs/10^3 km^2. It could be seen that the soil types formed under the combination of human activities and natural factors had a great influence on the distribution pattern of TVs.

Vegetation types

Vegetation distribution can reflect the local climate, soil, and water conditions, and the distribution of TVs varies greatly under different vegetation types (Table 4). The number of TVs in the cultivated vegetation type area was the highest, accounting for about 45% of the total TVs. In the areas of vegetation types such as taiga and shrub, the number of TVs was also large, and the number of TVs in these two vegetation types accounted for 21% and 17% of the whole country, respectively. The vegetation types with high traditional village densities were grassland, coniferous forest, cultivated vegetation, and shrub, and the village densities were 1.977 TVs/10^3 km^2, 1.756 TVs/10^3 km^2, 1.477 TVs/10^3 km^2, and 1.262 TVs/10^3 km^2, respectively. However, in the areas where the vegetation types were mixed broadleaf-conifer forest, desert, swamp, and alpine vegetation, the number of TVs was relatively small, and the aggregation degree of TVs was not high.

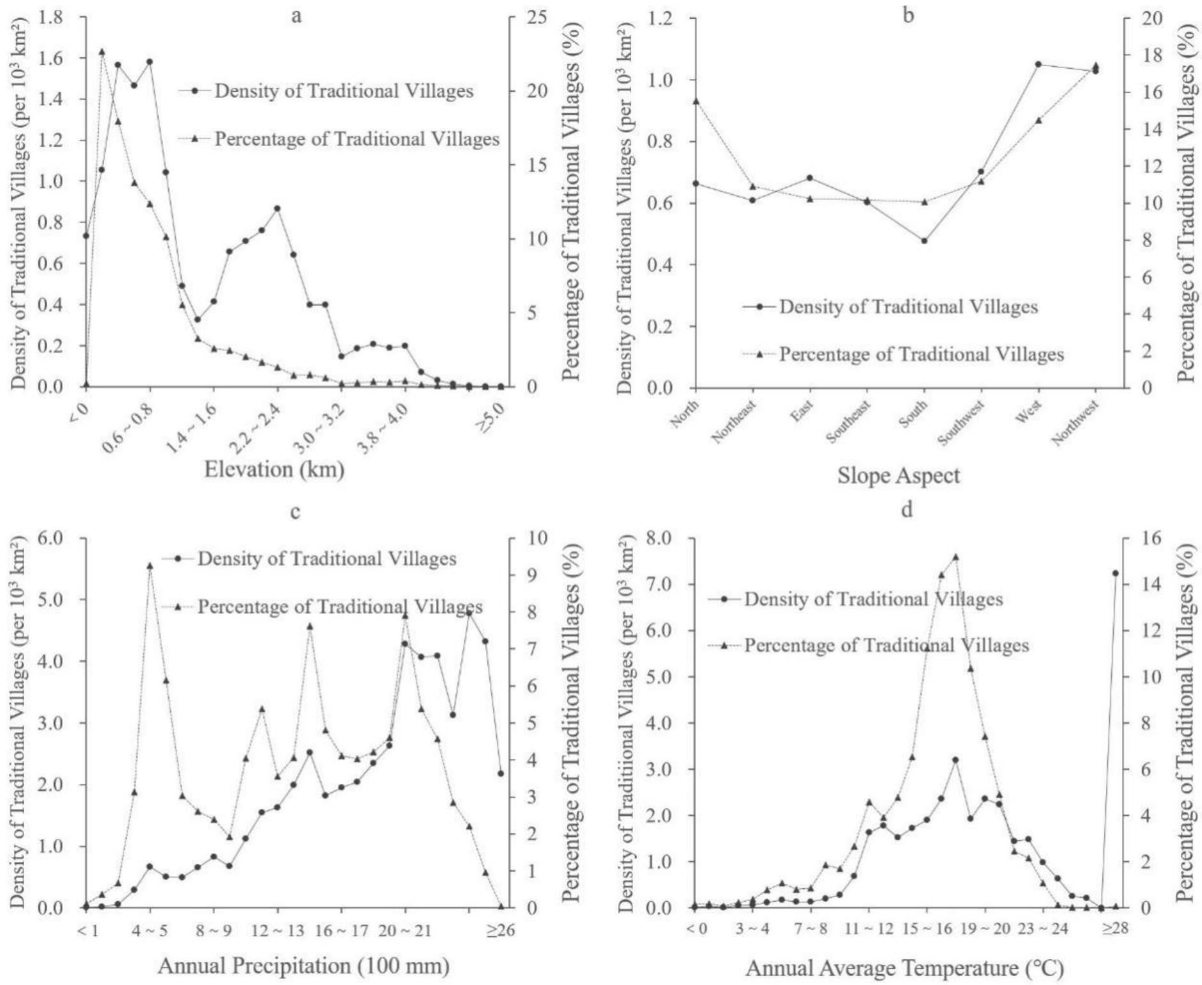

Fig. 5 Traditional villages in different terrains and climate conditions

Table 4 Traditional villages of different soil and vegetation types

Soil type	Percentage of villages (%)	Density of villages (per 10^3 km^2)	Vegetation type	Percentage of villages (%)	Density of villages (per 10^3 km^2)
Alfisol	4.618	0.297	Coniferous forest	20.721	1.756
Semi-alfisol	9.810	1.559	Mixed coniferous broad-leaved forest	0.000	0.000
Pedocal	2.427	0.279	Broad leaf forest	5.745	0.575
Aridisol	0.309	0.068	Shrubs	16.881	1.262
Desert soil	0.029	0.003	Desert	0.089	0.005
Amorphic soil	18.400	0.773	Grassland	1.226	0.059
Semi-aqueous soil	2.015	0.184	Brushwood	8.817	1.977
Aqueous soil	0.235	0.110	Meadow	0.798	0.053
saline-alkali soil	0.132	0.053	Marsh	0.148	0.158
Anthrosol	20.738	3.025	Alpine vegetation	0.015	0.003
Alpine soil	0.882	0.030	Cultivated vegetation	45.488	1.477
Ferralisol	39.947	2.429	Other	0.074	0.009
Other	0.456	0.140			

Population denisity and GDP

Villagers are the main body in the formation and development of a village, and the population has an important influence on the spatial distribution of TVs. According to Fig. 6a, with the increase in population density, the number of TVs gradually decreased. TVs were mainly distributed in areas with a population density of fewer than 500 people/10^3 km^2. The density of TVs varied but not evidently with the population density, reaching the maximum value at the population density of 7000–7500 people/10^3 km^2. There was also an important correlation between the regional economic situation and TVs, and the economy could affect the formation and spatial distribution pattern of TVs. With the increase in the GDP density, the number of TVs showed a gradually decreasing trend (Fig. 6b). In areas with a GDP density of fewer than 10 million yuan/km^2, the number of TVs was the largest, with about 64%, but the density was only 0.555 TVs/10^3 km^2, which was much lower than that of other areas. The village density was the largest in the regions with a GDP density of 50 million to 60 million yuan/km^2.

Hydrological conditions

Water is an essential material for human production and life, and a key factor affecting the spatial distribution of TVs. This study superimposed the TVs by using 0.1 km and 0.5 km as the buffer radius of the anastomosis, respectively. The distribution density of TVs in different river buffer zones was counted (Fig. 7a, b). The density of TVs varied greatly between 2 and 10 km in the buffer zone of different grades of rivers. Overall, the TVs had the highest density on the third-order river, followed by the density around the first-order river. Compared with the 1 km buffer radius, the density of TVs with a buffer radius of 0.1 km was higher. In the 10 km buffer zone, the distribution density of TVs in the 8.0–8.5 km buffer zone around the third-order river was the highest, with 2.035 TVs/10^3 km^2. The distribution density of TVs in the buffer zone of 1.5–2 km around the second-order river and the 0.5–1.0 km buffer zone of the first-order river was the highest. In general, the villages were relatively scattered within 10 km around the rivers at all levels. In the 2 km buffer zone, the traditional village density changed evidently. The density of TVs was the highest in the buffer zone of 0.5–0.6 km around the third-order river and the first-order river, and the highest in the buffer zone of 1.7–1.8 km around the second-order river. With the highest degree of village concentration within 0.2–0.3 km away from the river, after increasing the buffer distance, the density of TVs was decreasing.

Traffic location

The road is an important factor that determines the external connection of areas, affecting the aggregation of population, and is an important factor for the formation and development of TVs. To reveal the distribution pattern of TVs along roads, this study analyzed the buffer zones of main roads (railways, expressways, and national highways) in China. By spatial overlay with TVs, the distribution density characteristics of TVs in different road buffer zones in China were obtained. Specifically, this study established a 20-level road buffer zone with equal spacing of 0.5 km and 0.1 km, respectively (Fig. 7c, d). In the 10 km road buffer zone with a buffer radius of 1 km, the traditional village density was shown as expressways > railways > national highways. Figures 7c shows that the density of TVs around railways and national highways with a buffer radius of 0–0.5 km was the highest, and the

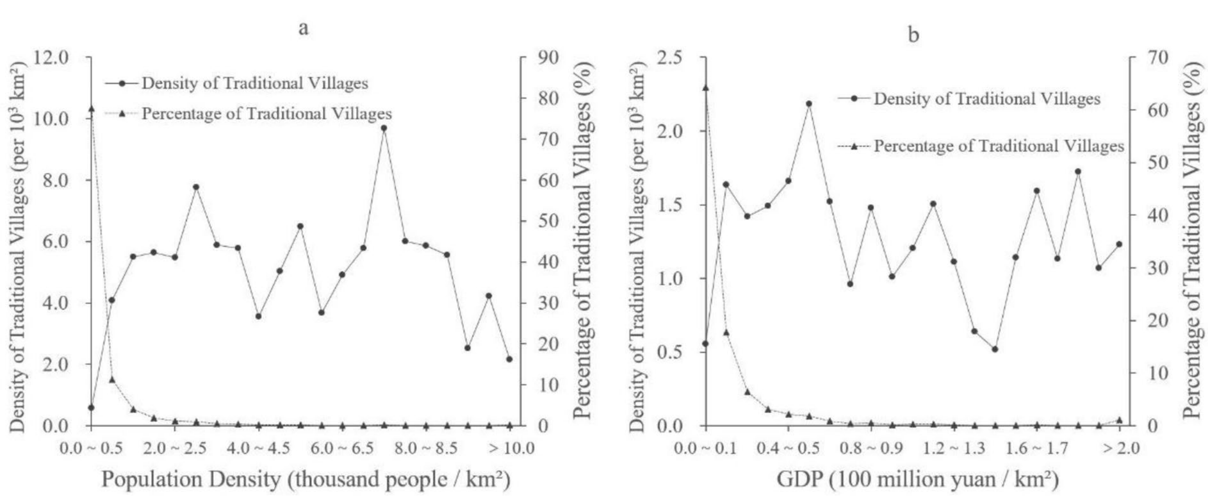

Fig. 6 Traditional villages in different population density and economic development levels

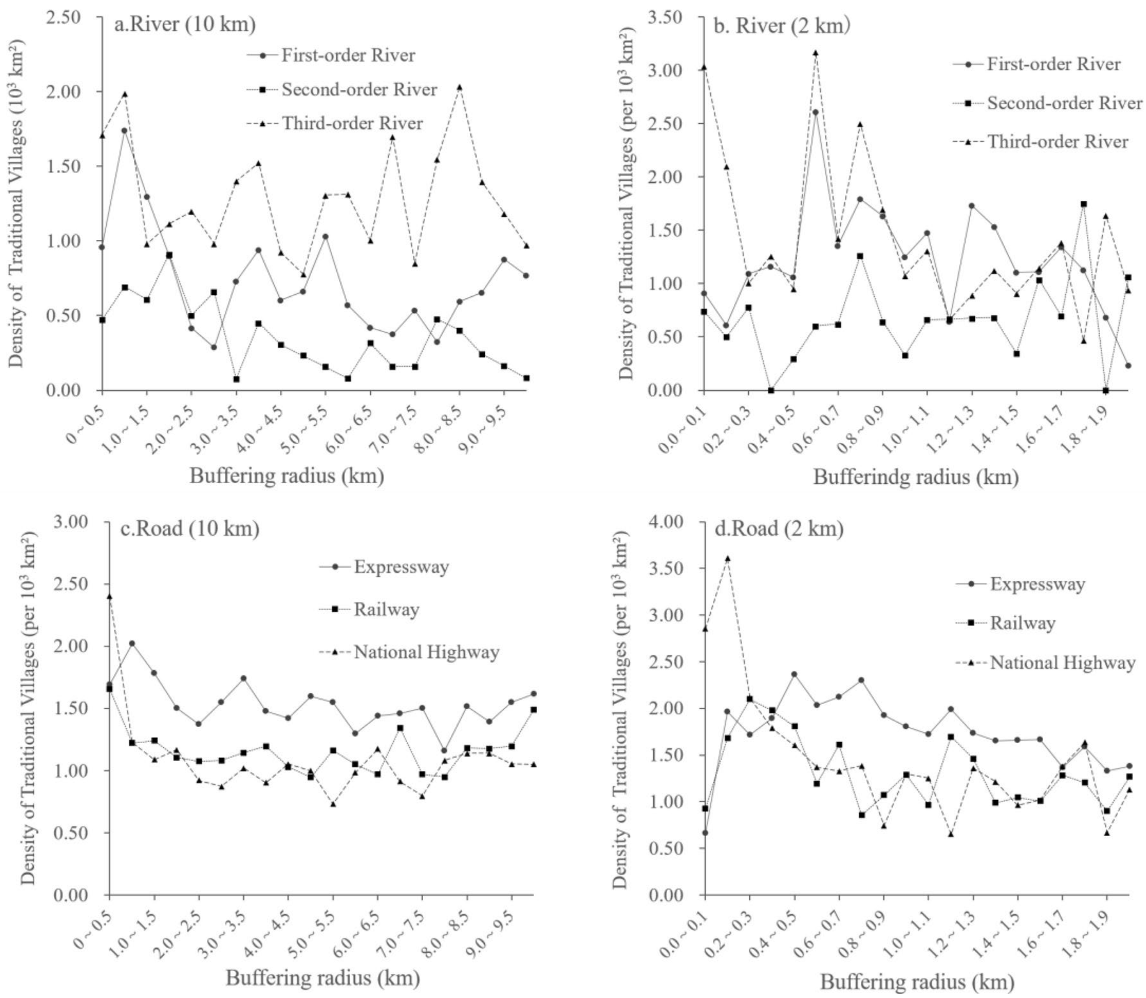

Fig. 7 Traditional villages in different rivers and road buffer zones

density of TVs around expressways with a buffer radius of 0.5–1.0 km was the highest. Figure 7d shows that the density of TVs around railways with a buffer radius of 0.2–0.3 km was the highest, the density of TVs around expressways with a buffer radius of 0.4–0.5 km was the highest, and the density of TVs around national highways with a buffer radius of 0.1–0.2 km was the highest. Within the buffer zone distance greater than 1 km, the distribution density curve of the TVs was relatively stable as the buffer distance increased, indicating that the TVs were more scattered around the road. Similarly, in the 2 km buffer zone, the lowest density of TVs within 0.1 km around the expressways was 0.666 TVs/10^3 km^2. The density of TVs increased with the increase of buffer distance and then decreased. In the buffer zone of 0.4–0.5 km around expressways, the largest density of TVs was 2.363 TVs/10^3 km^2. The density of TVs reached the maximum value in the buffer zone of 0.1–0.2 km around the national highway and 0.2 km–0.3 km around the railway. In general, the distribution of TVs along roads was obvious, and the density of TVs showed a decreasing trend with the increase in buffer distance.

History and culture

About 73% of China's intangible cultural heritage survives in TVs. As a concrete expression and important carrier of history and culture, intangible cultural heritage includes the physical objects and places related to the existing traditional cultural expressions. We analyzed the correlation between the percentage of TVs and the percentage of intangible cultural heritage in different provinces by using the point data of intangible cultural heritage and the point data of TVs. The results showed that the Pearson correlation coefficient was 0.557 and was significant at the 0.001 level. This showed that the spatial distribution of TVs and intangible cultural heritage had a high degree of consistency. This is because TVs are important places where intangible cultural heritage is generated, transmitted, and displayed, and intangible cultural heritage is an integral part of the culture and history of TVs.

Conclusion and discussion

Conclusion

Overall, the spatial distribution of Chinese TVs was mostly concentrated in the south and east. Guizhou, Yunnan, and Hunan were the three provinces with the most TVs, with 723, 708, and 658 TVs respectively. In contrast, Xinjiang Uygur Autonomous Region and Tianjin have only 4 TVs. The center of the standard difference ellipse of Chinese TVs was mainly distributed in the area from southeastern Guizhou to Hubei and Hunan, and the direction of the ellipse was northeast to southwest with stability. The spatial distribution of TVs from the first to the fifth batches was increasing in compactness. Through the global spatial autocorrelation test, we also found that the spatial distribution of TVs had significant spatial dependence. That is, TVs tended to exist in clusters.

As for the factors influencing the spatial distribution of TVs, we analyzed the correlation between natural, economic, and historical culture and the spatial distribution of TVs. Overall, it was concluded that TVs were mainly located at low elevations, on northern slopes, near third-order rivers, and in warm and humid areas. Ferralisol and cultivated vegetation were the main soil types and vegetation types in most TVs. Moreover, in terms of socioeconomic aspects, TVs were mostly located in areas with low levels of economic development, low population density, and rich history and culture. The impact of roads on TVs was not obvious.

Discussion

The increasingly dramatic urban–rural transition has intensified the non-agriculturalization of the agricultural labor force, and the rurality and regional culture of rural areas are facing a huge impact. The creation of the "List of Chinese TVs" and the proposal of the "National Strategic Plan for Rural Revitalization (2018–2022)" provide new opportunities for the protection, utilization, and development of TVs [21]. An in-depth exploration of the current spatial pattern characteristics, aggregation situation, and driving mechanism of Chinese TVs with high historical value and cultural connotation are crucial for further understanding of the spatial characteristics and formation mechanism of Chinese TVs. The spatial distribution of TVs is influenced by nature, social economy, and culture. Due to China's complex terrain, time-honored history, ethnic diversity, and rich culture, the long-term interaction of these factors affects the spatial agglomeration of TVs. This study analyzed the influence of natural geographical conditions and socioeconomic development on TVs but did not touch on the types, external forms, internal structures, architectural features, cultural connotations, and values of TVs. Therefore, in the following work, the analysis of the role of human activities and conceptual values in the distribution of TVs should be strengthened. It should also be unified with the study of the differentiation factors of TVs to further decipher the driving mechanisms of TVs and strengthen the summary of the spatial distribution patterns of different types and attributes of TVs.

Previous studies on TVs have focused on provincial, basin, and regional scales [21, 42], and there are still few studies based on national scales [14]. Extensive literature shows that TVs have significant spatial agglomeration characteristics at both regional and national scales [14]. This coincides with the conclusions reached in this study. In terms of drivers, studies on the influence of natural and socio-economic factors on the spatial distribution of TVs at the regional level have received attention [14, 21]. They found that topographic factors such as elevation and slope can significantly affect TVs' spatial patterns [42]. This study concludes that the spatial distribution of TVs at the national scale is still based on this pattern. In addition, socioeconomic factors control the continuous evolution of TVs, of which the influence of population and economy remains strong [21, 42]. TVs are mostly located in areas with low population density [42]. And the impact of economic development level on the spatial distribution of TVs shows different results in different study areas [21, 42].

Based on the results of this study, the following suggestions are proposed. First, China has a vast territory, and the distribution density of TVs and the way of development and utilization should be different in various regions. It is recommended to continue exploring the protection path of TVs and to formulate development approaches and protection measures for TVs according to local conditions. Second, TVs in China have significant spatial agglomeration characteristics. When developing and utilizing TVs, the Chinese government should consider spatial spillover, and cluster development and conservation of TVs can achieve twice the result with half the effort. Third, transforming the resource advantages of TVs into economic advantages and promoting the development of rural tourism with ethnic characteristics is of great practical significance. Finally, Regarding the influencing factors affecting the spatial pattern of TVs, the government should incorporate these influencing factors into the establishment of the traditional village protection and development system.

Author contributions
WC and ZY: writing-original draft, conceptualization, methodology, software, formal analysis; LY: writing-original draft; writing-review & editing, data curation; JB: data curation; JW: data curation; JZ and ZY: writing-review & editing; ZL: writing-review & editing.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Competing interests
The authors declare that they have no competing interests.

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