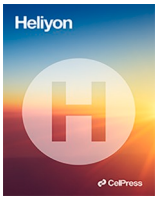
Heliyon 10 (2024) e27677

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



Research article

Spatial patterns, factors, and ethnic differences: A study on ethnic minority villages in Yunnan, China

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ARTICLE INFO

Keywords:
Ethnic minority villages
Spatial distribution
Ethnic differentiation
Natural factor
Human factor

ABSTRACT

This paper takes ethnic minority villages in Yunnan province of China, which have significant characteristics of multi-ethnic integration, as the research object. Through various spatial statistical analysis methods, we analyzed the overall distribution characteristics of ethnic villages in Yunnan, the distribution difference among various ethnic groups, and the influencing factors of the distribution pattern. It was found that: (1) The ethnic minority villages in Yunnan generally exhibit a kernel density characteristic of "three concentrated areas and multiple scattered points" and distribution characteristic of "hot spots in the west and cold spots in the east". Each ethnic group has a relatively concentrated region, presenting significant ethnic autocorrelation. (2) The differences in the relationship between villages and landscape among various ethnic groups have given rise to a unique three-dimensional distribution pattern, which is relate to ethnic origin and livelihood culture. Meanwhile, Han traditional villages tend to occupy areas with relatively better geographical conditions. (3) Natural factors, such as topographic relief, the distance between ethnic villages and rivers, and elevation, have a significant impact on the distribution of ethnic villages in Yunnan. Meanwhile, test results of social and human factors, including the distance from central cities, per capita GDP, and the gross annual output values of primary industry, indicate that the development of social economy and the promotion of urbanization pose challenges to the preservation of ethnic villages.

1. Introduction

Ethnic Minority Characteristic Villages (hereafter referred to as "EMCV") are a characteristic evaluation system of villages in China where ethnic minority populations are relatively concentrated and have a high proportion, comprehensive production and living functions, as well as distinct cultural and settlement characteristics of ethnic minorities [1]. China's rich ethnic minority culture is an important component of the global multicultural landscape, and the EMCVs are the main material carriers of these ethnic cultures, playing an important role in inheriting ethnic cultural diversity and revitalizing sustainable development in ethnic minority rural areas [2]. In recent years, due to historical, natural, economic, and other reasons, the spaces that bear and display ethnic cultures have been severely damaged. Consequently, the ethnic and rural characteristics of ethnic villages have rapidly disappeared. In response to these issues, China carried out a pilot work on the protection and development of ethnic minority villages and issued the "Outline of the Plan for the Protection and Development of Ethnic Minority Villages (2011–2015)",[1] then in 2014, the first batch of Chinese EMCVs (340)

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[1] National Ethnic Affairs Commission of China. [EB/OL]. https://www.neac.gov.cn/seac/zcfg/201212/1074566.shtml,2012-12-05.

https://doi.org/10.1016/j.heliyon.2024.e27677
Received 14 August 2023; Received in revised form 16 February 2024; Accepted 5 March 2024
Available online 11 March 2024

was named.[2] Moreover, various provinces (autonomous regions, municipalities) also conducted evaluations on local ethnic minority villages, reflecting the importance that the country attaches to the protection and development of ethnic minority culture in the new era.

1.1. Resource situation of ethnic minority villages in Yunnan, China

Yunnan Province is situated in the southwest border of China, the southeast of the Qinghai-Tibet Plateau, and the southwest of the Yunnan-Guizhou Plateau. It shares land borders with Myanmar, Laos, and Vietnam, totaling 4061 km [3][3] (Fig. 1). It is a historical border area where many ethnic groups migrated and frequently communicated, leading to the convergence of diversified cultures. The border policies, such as the Jimi system and the Native Chieftain System, implemented in Yunnan during feudal times objectively contributed to the retention of numerous ethnic groups in the region [4]. Since the late Ming Dynasty, the substantial influx of Han people has significantly impacted the settlement patterns of ethnic minorities in Yunnan. However, to this day, it remains the frontier province with the greatest number of ethnic minorities, unique ethnic minorities, and ethnic autonomous regions in China, epitomizing the pattern of pluralistic integration of the Chinese nation. According to the fifth population census of China, there are a total of 51 ethnic minorities residing in Yunnan, accounting for 33.6% of the total population in the province. Among them, there are 25 ethnic minorities with a population of over 5000 [3][281]. The land area of ethnic minority autonomous regions in Yunnan accounts for 70.2% of the total area of the province, including 8 ethnic autonomous prefectures, 29 ethnic autonomous counties, and 140 ethnic townships.[3] Among the three batches of national EMCVs (1652 in total),[4] there are 247 in Yunnan Province, ranking second in the country in number. Conducting research on the distribution characteristics and influencing factors of the EMCVs in Yunnan is of reference significance for exploring the protection and inheritance paths of ethnic minority villages and their characteristic cultures.

1.2. Literature review

1.2.1. Research on ethnic minority villages

The cultural characteristics and the protection and development of ethnic minority villages have received attention from disciplines such as architecture, ethnology, sociology, economics, and geography. International scholars' research on ethnic settlements or communities encompasses the types and changes of ethnic communities [5–7], tourism development [8–10], protection of ethnic settlements and buildings [11,12], protection and inheritance of ethnic culture [13,14], and more. Chinese scholars' research on ethnic minority villages mainly focuses on the following aspects: evaluation of historical and cultural value or development potential [15–17], exploration of protection and development paths [18–22], spatial morphological characteristics and evolution laws [23–26], intangible cultural characteristics and their inheritance [27–29], and the regional spatial distribution characteristics and their impact mechanisms [30–43]. The research topic of this article falls into the latter category.

1.2.2. Research on the spatial distribution of villages

The distribution pattern of ethnic minority villages in geographical space is a comprehensive manifestation of the adaptation of ethnic minorities to the natural environment, historical development, and social economy in a certain region. It is an important component of minority cultural research. It also provides a practical reference for constructing the protection system for ethnic villages. Previous research on the spatial distribution of traditional villages has been conducted at different scales, including national, provincial, municipal, and watershed levels [30–33]. They mainly explored the influencing factors of villages distribution from both natural and cultural perspectives, specifically covering factors such as altitude and topographic relief, slope and aspect, climate, population, transportation, social economy, etc. [35,41] In terms of research methods, spatial analysis techniques, such as kernel density estimation, nearest neighbor index, and Moran index are primarily employed to analyze the spatial distribution characteristics of villages. These methods are combined with spatial statistical techniques, including overlay analysis, spatial neighborhood analysis, buffer zone analysis, and weighted regression model, to explore the correlation between the spatial distribution of villages and influencing factors [34,37,38]. In recent years, some scholars have utilized a tool specifically designed for analyzing the correlation of factors distributed in geographical space, namely geographic detectors, to comprehensively calculate the explanatory power of various factors on the spatial differentiation of villages [35,36,39,40].

1.2.3. Research gap

The above research provides a sufficient theoretical framework and methodological reference for this study, yet there is also room for further exploration and research. Firstly, various types of ethnic minorities are distributed in remote areas in China; however, there is regional imbalance in existing research. Ethnic minority villages in Hubei, Guizhou, and Hunan have been studied the most frequently, while research in Yunnan is relatively scarce [44]. Secondly, in previous studies on the distribution pattern of ethnic villages in large regions, scholars found it difficult to determine the main ethnic group of each village in ethnic regions due to the

[2] National Ethnic Affairs Commission of China. The National Ethnic Affairs Commission named the first batch of "Chinese Ethnic Minority Characteristic Villages" [EB/OL]. https://www.neac.gov.cn/seac/xwzx/201409/1002845.shtml, 2014-09-26.

[3] Yunnan Provincial Bureau of Statistics. 2020 Statistical Yearbook of Yunnan Province [EB/OL]. https://stats.yn.gov.cn/tjnj/tjnj.

[4] The list of three batches of Chinese EMCVs were published by National Ethnic Affairs Commission of the People's Republic of China in 2014, 2017, and 2020 (http://www.seac.gov.cn/).

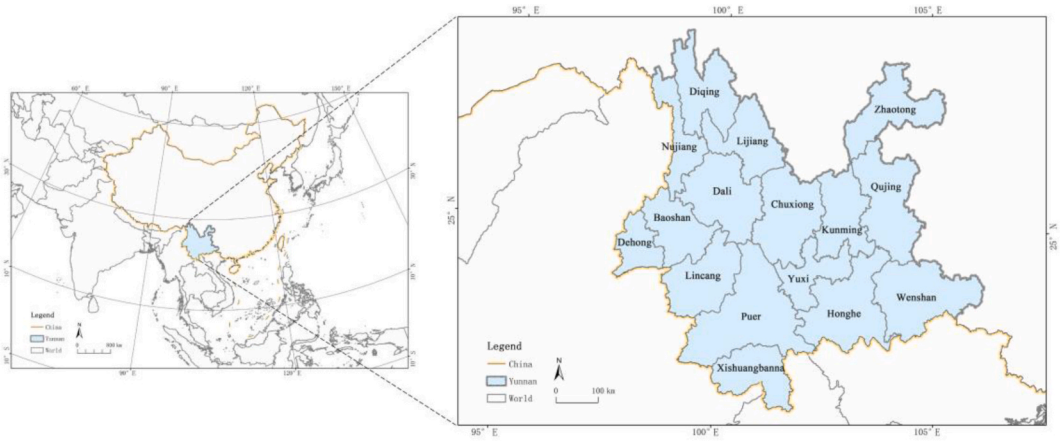


Fig. 1. The location of Yunnan Province.

limitations of various survey methods. Therefore, most studies failed to distinguish and compare the distribution pattern of different ethnic villages, resulting in various ethnic villages being commonly analyzed as a whole [30,32,38,41].

1.3. Research objectives

This study benefited from the team's years of extensive research on the cultural geography of traditional villages and dwellings in southern China. This period allowed the establishment of a mature regional research framework and rich cognitive accumulation for traditional villages. We conducted several large-scale in-depth surveys in Yunnan Province and obtained detailed data on ethnic minority villages. Based on this, this study aims to achieve the following objectives: 1) To explores the overall distribution characteristics of EMCVs in Yunnan and their impact factors by integrating data of EMCVs at all levels for the first time with precision at the city and county levels; 2) To characterize the differentiation patterns of different ethnic groups from the perspective of ethnic differences by conducting comparative analysis between EMCVs and Han traditional villages, as well as among EMCVs of different ethnic groups. It is expected that this study can contribute to expand the research content of ethnic villages and to provide useful research data for the zoning, classification, and diverse protection of ethnic villages.

2. Materials and methods

The 247 national EMCVs in Yunnan province were selected from the lists of the three batches of Chinese EMCVs published by National Ethnic Affairs Commission of the People's Republic of China (http://www.seac.gov.cn/) in 2014, 2017, and 2020. The 351 provincial EMCVs came from two batches of EMCVs published by Ethnic and Religious Affairs Commission of Yunnan Province (http://mzzj.yn.gov.cn/) in 2017 and 2020. After eliminating samples from national and provincial villages, a total of 511 EMCVs constitute the sample set of this study. The attribute information of each village includes longitude, latitude, elevation, and ethnicity. The geographical coordinates and elevation are from the 91 Satellite Map Assistant Enterprise Edition (https://www.91wemap.com/index.htm). The main ethnic information of each EMCV was collected from the consultation of Ethnic and Religious Affairs Commission of Yunnan Province and Ethnic and Religious Affairs Bureau of autonomous prefectures (cities) in Yunnan Province. For multi-ethnic villages, the ethnic attribution is defined by the main ethnic group with the largest population and most prominent cultural characteristics in a village. The administrative boundary vector map, river system, and 90 m resolution DEM digital elevation data were obtained from Resource and Environment Science and Data Center of the Chinese Academy of Sciences (https://www.resdc.cn). Population, economy, and other relevant statistics of Yunnan Province and all autonomous prefectures (cities) and counties (county-level cities and county-level districts)[5] were obtained from the 2020 Statistical Yearbook of Yunnan Province.[6]

The collected data were all located in the corresponding geographic locations in the GIS system in the form of point features. On this basis, spatial analysis tools such as the nearest neighbor index, kernel density estimation, Moran index, and Getis Ord G * hot spot in GIS can be directly used to analyze the spatial distribution characteristics of the EMCV point sets. Among them, the nearest neighbor index and Moran index can both be used to measure whether the distribution of point sets in geographic space is scattered or clustered, while kernel density estimation and Getis Ord G * hot spot can help us intuitively reflect the distribution and clustering position of discrete point sets in continuous spatial areas. Regarding the analysis of factors related to the distribution of EMCVs, we mainly used comprehensive statistics based on Geodetector and overlay analysis based on GIS. The former is an tool embedded in the Excel

[5] The concept and data of county level appearing later in the article include county level cities and districts, which will not be annotated again for brevity.

[6] Yunnan Provincial Bureau of Statistics. 2020 Statistical Yearbook of Yunnan Province [EB/OL]. https://stats.yn.gov.cn/tjnj/tjnj.

platform, which are specifically designed to quickly calculate the degrees of correlation between the distribution of a certain element in geographic space and multiple other elements (factors). Overlay analysis, on the other hand, involves overlaying the EMCV points with other geographical maps to obtain information on the geographic location of the EMCV points, such as elevation, terrain, and river distance, in order to statistically analyze the distribution of EMCV and their relationships with other elements. The methods and their indicators mentioned above are shown in Table 1.

3. Spatial distribution characteristics of EMCVs in Yunnan

3.1. The overall distribution of EMCVs

The 511 EMCVs are distributed among the 16 autonomous prefectures (cities) of Yunnan. Dali has the largest number, accounting for 14.09%, while Kunming, the provincial capital of Yunnan, has the least (3.13%), except for Diqing (2.35%). In county-level statistics, EMCVs are distributed in 115 of 129 counties in Yunnan. It is worth noting that all 25 border counties in Yunnan except Lvchun County have EMCVs, accounting for 31.5% of the whole province, with 72% of them densely distributed in the border zone of west and southwest Yunnan (Fig. 2).

According to the nearest neighbor index test (No.1 in Table 1), the EMCVs in Yunnan present a clustered distribution pattern in space (Fig. 3). The negative Z-score (−16.095) indicates clustering, and the *P*-value < 0.01 suggests that the probability of randomly generating clustering patterns is less than 1%。As observed in the nuclear density map (Fig. 4), the EMCVs in Yunnan are distributed unevenly with three high-density cores in the center of Dali, the southwest of Lincang, and at the border of Yuxi and Honghe. Around these cores, continuous distribution belts were formed including northwest belt, southwest Yunnan belt and the center belt respectively. The EMCVs in other regions are patchy and scattered.

The Moran index analysis at county level was also carried out with the result shown in Fig. 5. A Z-score of 6.177 indicates a clustered pattern with a less than 1% likelihood of randomly generation, i.e., the spatial distribution of EMCVs has a significant positive spatial autocorrelation. Through further analysis of cold and hot spots (Fig. 6), Yunnan Province was roughly divided into two parts, i.e., hot spots in the west and cold spots in the east, bounded by the Yuanjiang valley and a wide valley at the southern end of the Yunling Mountains. The three hot spots are concentrated in Yuanjiang County of Yuxi City, the west area of Lincang City, and the border areas of Dali, Nujiang, Diqing, and Lijiang City, corresponding to the three cores of the nuclear density map. One high cold spot area is concentrated in the center of Kunming City, with sub cold spots surrounding it. Another sub cold spot is located in the south of Honghe.

3.2. Quantity and distribution of EMCVs of different ethnic groups

The 511 national and provincial EMCVs in Yunnan include 25 ethnic minorities, fully reflecting the multi-ethnic cultural characteristics of Yunnan. The number of Yi, Dai, and Bai villages ranks among the top three, accounting for 48.72% of the total. Among them, Yi villages have the largest number, with 137, accounting for 26.81%. The number of Mongolian, Shui, and Manchu villages is the lowest, with only one each (Table 2).

The global spatial autocorrelation analysis of the ethnic attributes of EMCVs with a Z-score of 22.56 and *P*-value<0.001, indicates a significant ethnic spatial autocorrelation, that is, each ethnic group has strong regional agglomeration (Fig. 7). The distribution nuclear density map of EMCVs for the nine main ethnic groups shows that the villages of each ethnic group have concentrated distribution areas. The EMCVs of Yi, Miao, and Dai have multiple high-density distribution cores (Fig. 8(a–c)), while the Bai, Naxi, Wa, Zhuang, Tibetan and Nu groups have only one obvious aggregation area (Fig. 8(d–i)).

4. Analysis of the influencing factors on the spatial distribution of EMCVs

The spatial distribution characteristics of EMCVs are jointly shaped by the natural and cultural environment. Natural factors primarily influenced the selection and settlement of ethnic villages in history, while current human factors mainly reflect the impact of contemporary socio-economic development on the preservation of traditional villages. Drawing on the analysis models commonly used in previous studies of the same type [30,31,35–37], and considering the completeness and accuracy of the obtained data, this study ultimately selected five types of influencing factors from the two categories of natural environment and social humanities for analysis. These factors include river system, topography, ethnic population, distance from central cities, and the local socio-economic development level.

Single-factor analysis is conducted through overlay analysis by superimposing the EMCV distribution map with the river system map, digital elevation map, central city distribution map, etc., to create a new multi-factor layer. Relevant data indexes are then obtained through special neighborhood analysis and buffer analysis. Further comparative analysis was made with a sample of Traditional Han villages[7] (hereafter referred to as "THVs") to explore the distribution characteristics of EMCVs as minority cultural groups. Differences among various ethnic minorities were also analyzed.

Finally, a comprehensive analysis of multiple factors on the overall distribution of EMCVs in Yunnan is conducted on Geodetector to determine the degree of impact of different factors.

[7] The 183 Han traditional villages are from the first to fifth batch of Chinese traditional villages in Yunnan Province with a predominantly Han population. All the list of THVs are published by the Ministry of Housing and Urban-Rural Development of China on https://www.mohurd.gov.cn/.

Table 1
Measurement indicators and their geographical spatial meanings.

No.	Index (Variable)	Formula	Parameter Description	Spatial Geographical Meaning
1	Nearest neighbor index (R)	$R = \overline{r_1}/\overline{r_E}$; $\overline{r_E} = 1/(2\sqrt{D})$	R is the nearest neighbor index , $\overline{r_1}$ Is the actual closest distance; $\overline{r_E}$ Is the theoretical closest distance; D represents the point density; When R = 1, the distribution of point elements is random; R > 1, the point elements tend to be uniform; R < 1, point elements tend to be condensed	It's a geographical indicator indicating the proximity of point elements in geographical space [34]
2	kernel density estimation f(x)	$f(x) = \frac{1}{nh}\sum_{i=1}^{n} k\left(\frac{x-x_i}{h}\right)$	f(x) is the estimated kernel density , $k\left(\frac{x-x_i}{h}\right)$ is the kernel function; h is the search bandwidth , nis the number of point elements; $(x - x_i)$ represents the distance from estimated points x to x_i	Reflecting the degree of condensation by the spatial distribution of point density [35,45]
3	Moran index (I)	$I = Z_i \sum_{i=1}^{n} W_{ij} Z_j$	I is the Moran index; Z_i、 Z_j represent the standardized values of the observed values of space unit i and j; W_{ij} is the space weight	It represents the spatial correlation between point elements and adjacent points [36]
4	Cold and hot analysis (G_i)	$G_i = \sum_i x^j W_{ij}/\sum_j x_j$ $Z = G_i - E(G_i)/\sqrt{Var(G_i)}$	x_i、 y_j represent the number of villages in region i and region j respectively; W_{ij} represents the space weight function; E(G_i) is the expected value; Var(G_i) is the coefficient of variation	It's used to measure the spatial dependence intensity between a point and other points within the range of distance [30]
5	Geodetector (Q)	$Q = 1 - \frac{1}{N\sigma^2}\sum_{h=1}^{L} N_h \sigma_h^2$	h = 1 , ,L is the stratification of variable Y or factor X; N_h and N are the number of units in layer h and the whole area respectively; σ_h^2 and σ^2 are the variances of layer h and region Y values respectively	It's used to detect whether a factor affects the reason for the spatial differentiation of a certain indicator value, and the degree of strength [46]

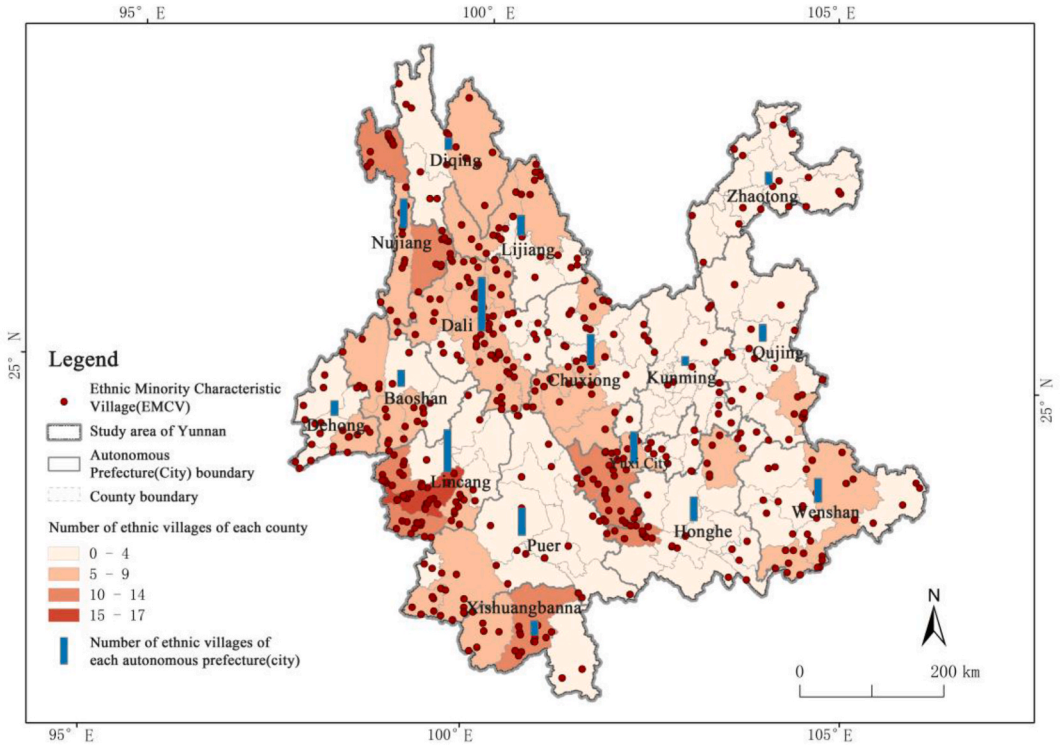


Fig. 2. Spatial distribution of EMCVs in Yunnan province.
Note: All maps in this article are derived from standard maps issued by the Ministry of Natural Resources of China.

4.1. Natural environmental factors

4.1.1. River system

Yunnan has a wide range of rivers and well-developed water systems, providing villages with stable production water and fertile soil. Moreover, rivers were important transportation routes in the early period, and as channels for the migration and flow of ancient

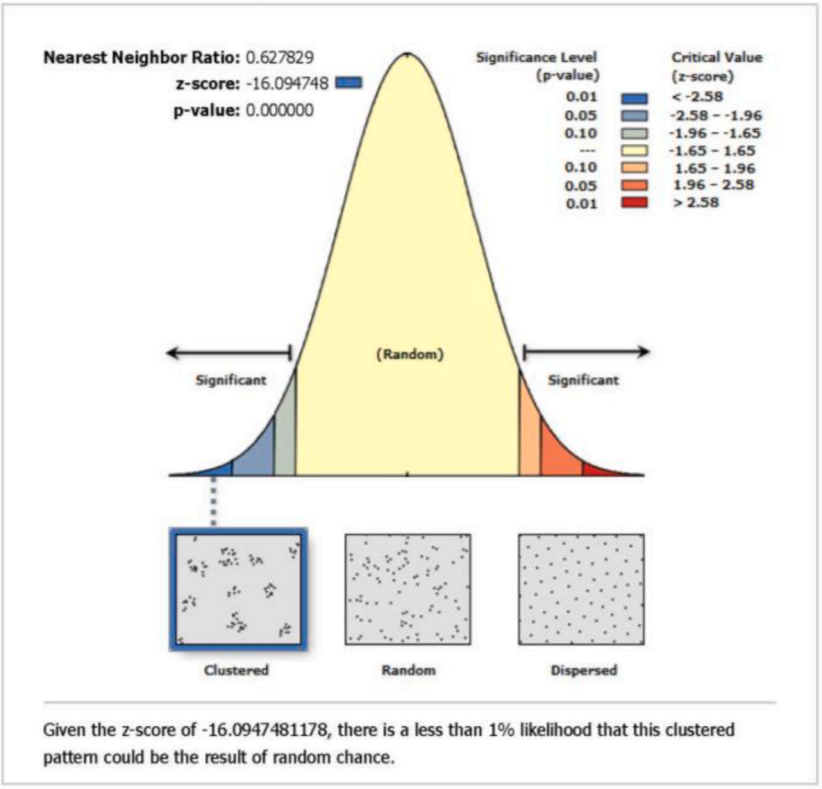


Fig. 3. The Average Nearest Neighbor test report.

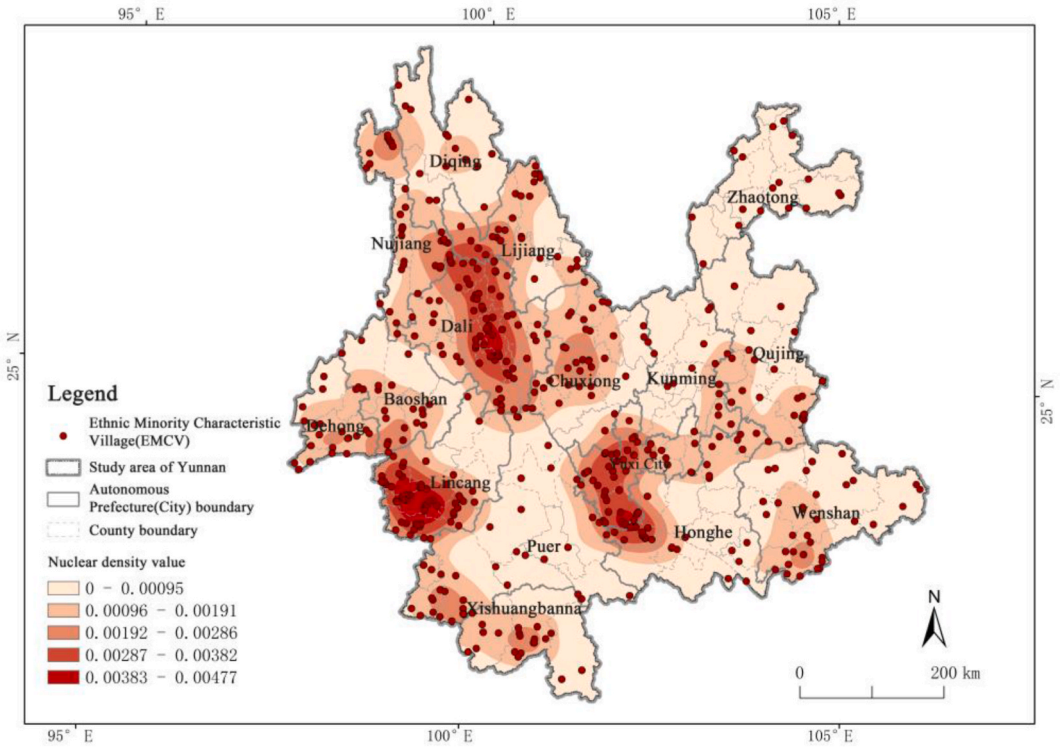


Fig. 4. The nuclear density map of EMCVs in Yunnan.

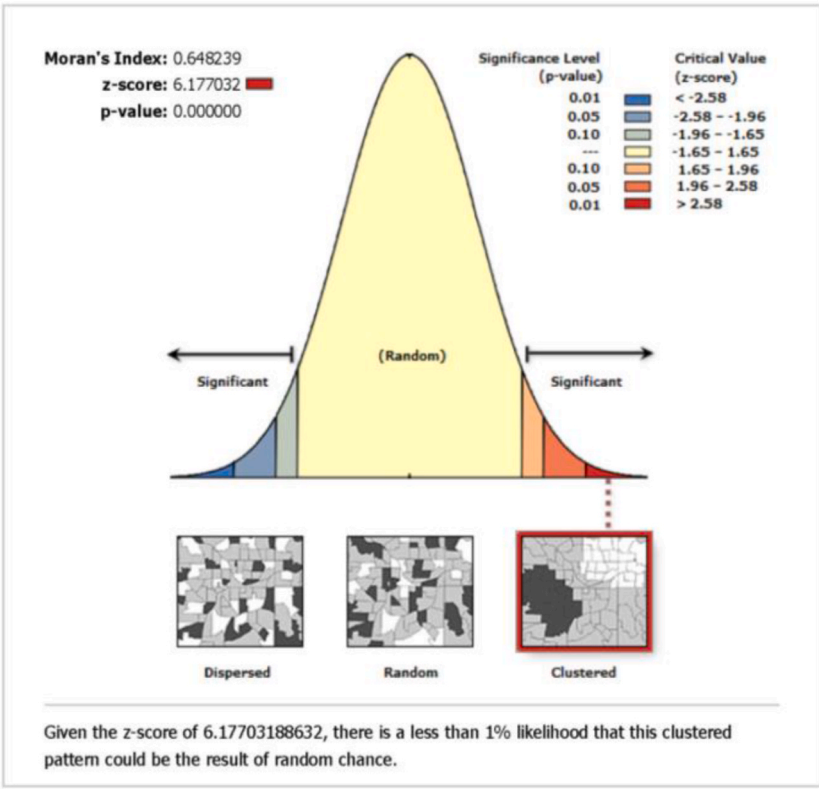


Fig. 5. The global spatial autocorrelation test report.

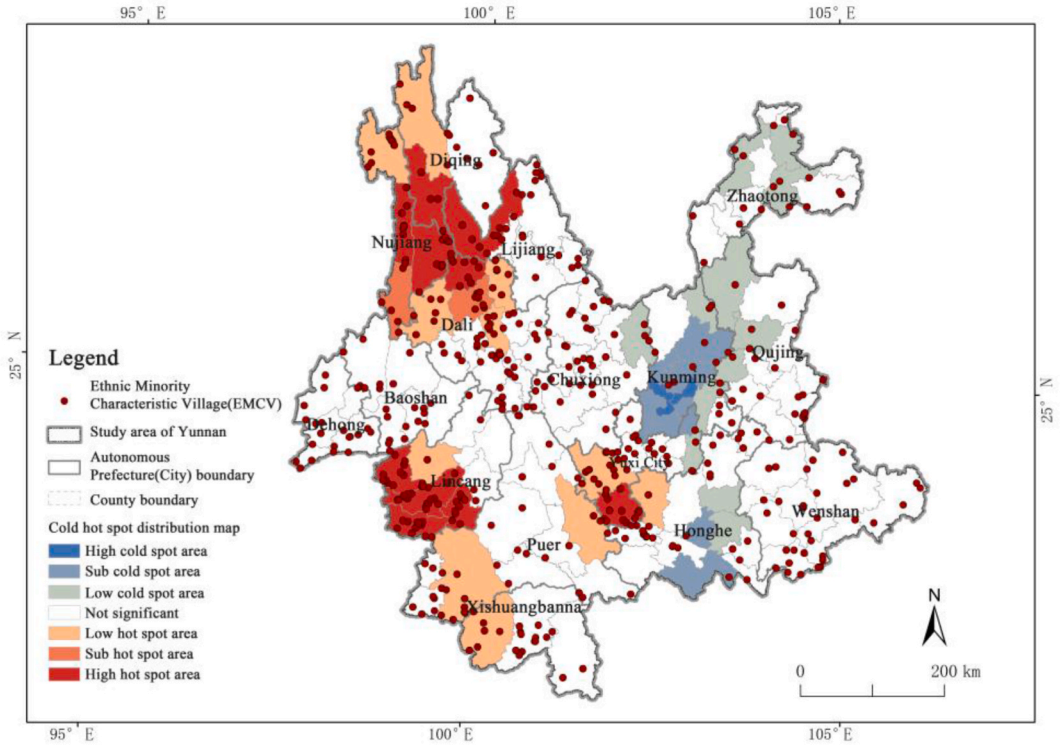


Fig. 6. Cold and hot spot distribution of EMCVs in Yunnan.

Table 2
Statistics on the quantity of EMCVs by ethnic group.

Ethnic	Quantity	Ethnic	Quantity	Ethnic	Quantity	Ethnic	Quantity	Ethnic	Quantity
Yi	137	Hani	26	Naxi	13	Jingpo	9	Achang	3
Dai	71	Wa	22	Pumi	13	Deang	8	Jinuo	2
Bai	41	Zhuang	20	Tibetan	12	Buyi	6	Mongolian	1
Lisu	32	Bulang	17	Lahu	11	Dulong	4	Shui	1
Miao	31	Hui	17	Nu	10	Yao	3	Manchu	1

Note: For multi-ethnic village, the ethnic attribution is defined by the main ethnic group with the largest population and most prominent cultural characteristics in a village.

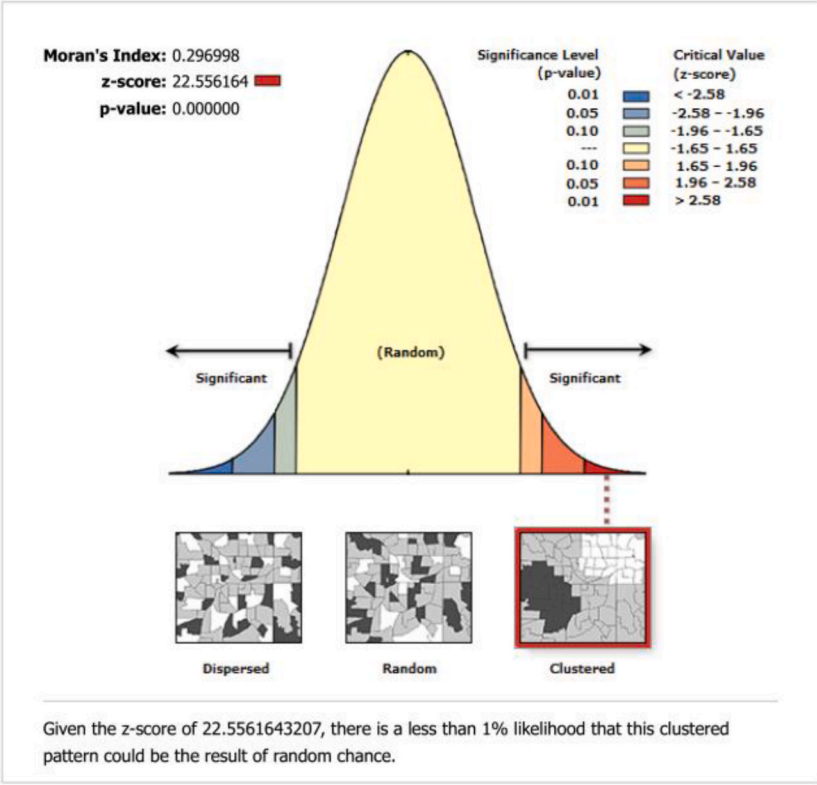


Fig. 7. The global spatial autocorrelation of the ethnic attributes of EMCVs test report.

ethnic groups. This paper analyzes the relationship between the distribution of EMCVs and the river system in Yunnan by calculating the distance from villages to their nearest river, with the grade of the river also taken into account.

The statistical results show that the majority of EMCVs are located within 2 km from the river, accounting for 33.27%. As the distance from the river increases, the number of EMCVs decreases (Fig. 9). The distribution pattern of THVs with river distance is generally similar to that of EMCVs, but the proportion of THVs less than 2 km from the river is much higher than that of EMCVs. Since the Qin and Han dynasties, Han immigrants began entering Yunnan, especially during the Yuan, Ming, and Qing dynasties when a large number of Han immigrants moved into the hinterland of Yunnan. Due to the developed economy, advanced technology, and high cultural level of the Han nationality, they were able to occupy better positions suitable for agricultural production and settlement. Meanwhile, ethnic minorities were either assimilated by the Han nationality or to migrated to mountainous areas with relatively harsh environments.

In addition, by exploring the distribution of EMCVs and THVs along the level of the nearest river (Fig. 9), it can be observed that the number of EMCVs and THVs distributed near sixth-grade rivers is the largest, accounting for 53.82% and 60.11%, respectively, followed by fifth-grade rivers. EMCVs and THVs located near rivers above grade 4 accounted for only 20.94% and 20.22%, respectively. Rivers of a higher grade (grade 1 or 2), like Nujiang River, Lancang River, Jinsha River, and other major rivers in Yunan, have deep canyons and strong currents. Areas around these rivers are more prone to mountain torrents and are not conducive to human habitation. It can be seen that, for both THVs and EMCVs, areas near small-scale rivers above grade 5, with weaker flood scouring and less destructive impact on villages, are more livable.

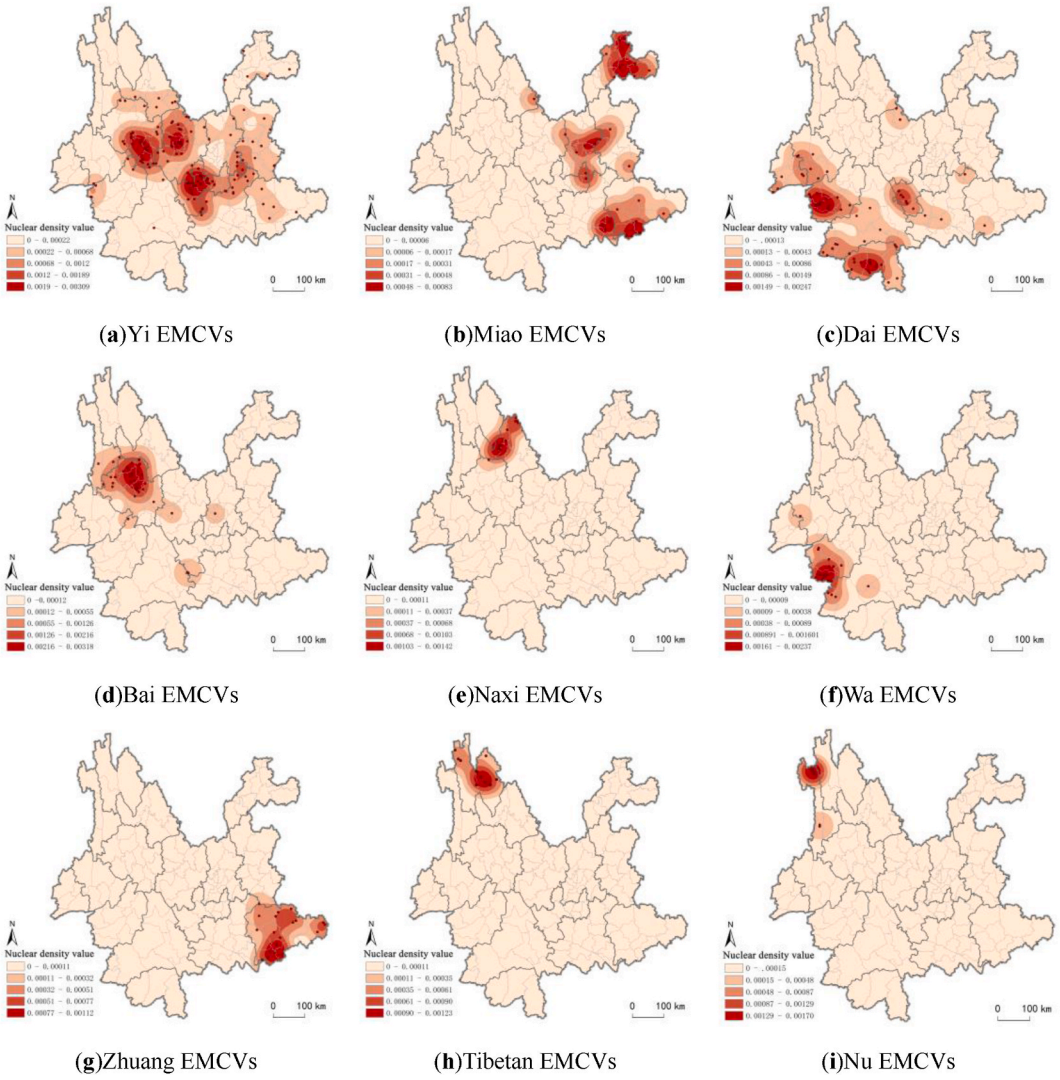


Fig. 8. The Kernel density distribution of EMCVs in Yunnan of (**a**)Yi EMCVs, (**b**)Miao EMCVs, (**c**)Dai EMCVs, (**d**)Bai EMCVs, (**e**)Naxi EMCVs, (**f**)Wa EMCVs, (**g**)Zhuang EMCVs, (**h**)Tibetan EMCVs, (**i**)Nu EMCVs.

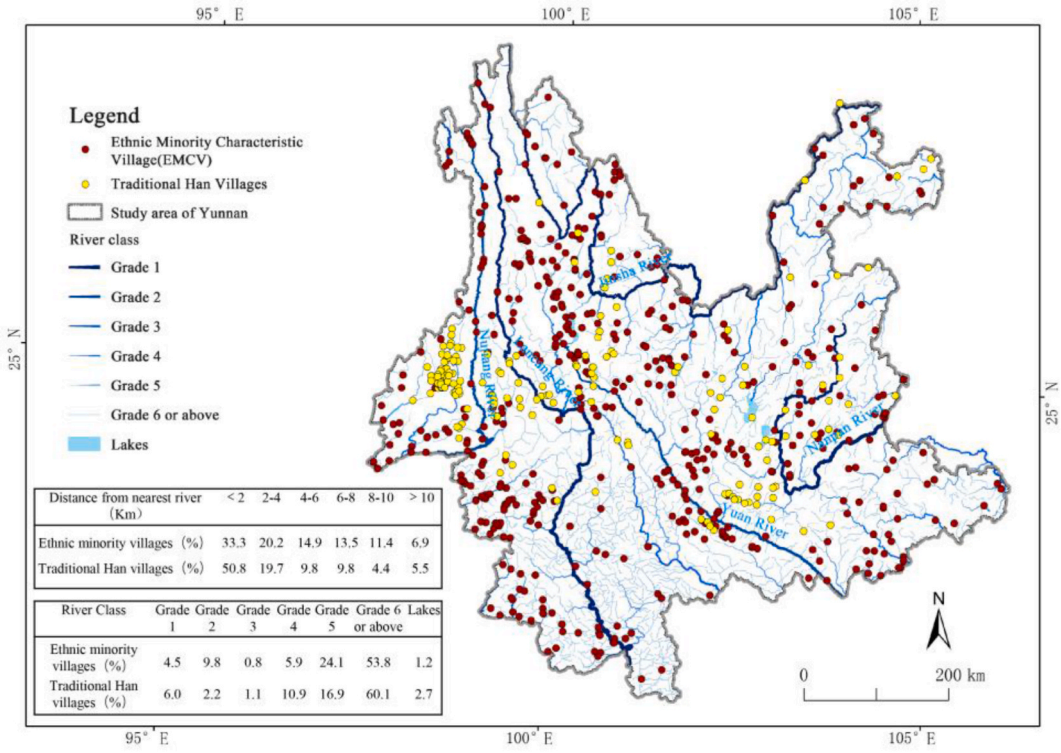
Further statistical analysis of the average distance from EMCVs of different ethnic groups (with a quantity of EMCV greater than 10) to rivers was conducted. According to the one-way ANOVA test in SPSS, there is a significant difference ($P < 0.001$) in the mean distance from EMCVs among different ethnic groups to rivers. As shown in Table 3, the average distance between Dai villages and the river is the closest, only 1760 m, while the average distance between Pumi villages and the river is the farthest, 5300 m.

The distribution characteristics are influenced by different livelihood styles [47,48]. Ethnic groups like Dai and Zhuang are typical rice-farming groups, demonstrating a closest relationship with rivers. Especially for the Dai groups, known as "the people of water", water is not only the source of livelihood but also a spiritual sustenance. The Water-splashing Festival of Dai has become an important festival for ethnic groups to interact with water. Hani groups, who are relatively distant from the river, have created the world cultural heritage, the Honghe Hani Rice Terraces, through excellent water storage technology adapted to the water-scarce areas of the Yunnan-Guizhou Plateau. On the other hand, Naxi and Pumi, who are farthest from the river, originated from a nomadic lifestyle, with animal husbandry being an important mode of livelihood. Although they also engaged in farming after entering the Central Plains, they primarily practiced mountain farming and rarely had paddy fields.

4.1.2. Topography

Topography can be represented by two main indicators: elevation and relief amplitude. The former reflects the location of villages in vertical geographic space, while the latter indicates the degree of topographic change, directly influencing the construction of villages and affecting their site selection and distribution.

By overlaying village samples with elevation data and employing extraction analysis, elevation data for each village can be



Distance from nearest river (Km)	< 2	2-4	4-6	6-8	8-10	> 10
Ethnic minority villages (%)	33.3	20.2	14.9	13.5	11.4	6.9
Traditional Han villages (%)	50.8	19.7	9.8	9.8	4.4	5.5

River Class	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6 or above	Lakes
Ethnic minority villages (%)	4.5	9.8	0.8	5.9	24.1	53.8	1.2
Traditional Han villages (%)	6.0	2.2	1.1	10.9	16.9	60.1	2.7

Fig. 9. Distribution of EMCVs and THVs along rivers of different distance and grades.

Table 3
The average distance between EMCVs of different ethnic groups and their nearest rivers (Km) .

Dai	Hui	Zhuang	Tibetan	Lahu	Bai	Wa	Bulang	Yi	Hani	Lisu	Miao	Naxi	Pumi
1.76	1.95	2.28	2.43	2.44	2.65	2.7	3.15	3.3	3.4	4.0	4.15	4.78	5.31

obtained and categorized into six grades at intervals of 500 m. The bar chart in Fig. 10 reflects the proportion of EMCVs on different elevation segments relative to the total. The proportions of land area at each elevation grade to the total area of the whole province were also calculated as a reference (represented by the red line). The statistical results show that as the elevation rises, EMCVs and Han nationality villages are distributed more intensively, reaching the maximum in the elevation range of 1500~2000 m. Thereafter, the proportion of EMCVs and Han nationality villages gradually decreases with the increase in elevation. Villages of both groups are only sporadically distributed above 2500 m. Overall, the elevation distribution characteristics of EMCVs and THVs are relatively similar, consistent with the proportion of land area at different elevations in Yunnan. However, the distribution differences of THVs in different elevation ranges are more significant, with 2/3 THVs concentrated in the elevation range of 1500~2000 m.

According to the grading standards issued by the Resource and Environment Science and Data Center of Chinese Academy of Sciences, the relief amplitude is divided into six grades [49]. The proportion of each grade in Yunnan is represented by the red line as a reference (Fig. 11). The statistical results show that both the EMCVs and Han ethnic villages are rarely distributed in plains and terraces. It is worth noting that EMCVs are most distributed in slightly-undulating mountains, consistent with the proportions of the overall landform, while THVs are most distributed in hilly areas, which only account for 14% of the province's area. It can be seen that in the context of modern urbanization spreading from plains with better development conditions to the surrounding areas, the retention of THVs still occupies a relatively more favorable geographical space than EMCVs.

We further investigated the differences in vertical spatial distribution among different ethnic groups. According to the one-way ANOVA test in SPSS, there is a significant difference ($P < 0.001$) in the mean distribution elevation among different ethnic groups. Table 4 shows the average elevations of EMCVs of each ethnic group (with a number of EMCVs greater than 10). The Tibetan, Pumi, and Naxi villages are distributed at the highest elevation in the high and middle mountain areas of northwest Yunnan, while the average altitudes of Dai and Zhuang villages are the lowest, mainly distributed in the valley area of southern Yunnan.

The terrain of Yunnan is high in the west and low in the east, high in the north and low in the south, presenting a stepwise descending characteristic. In the vertical direction of local areas, there are significant differences in the natural environments. Influenced by multiple factors such as living habits, migration time sequence, the number of indigenous peoples, ethnic struggles, and the difficulty of regional development, various ethnic groups have formed a vertical distribution pattern and diverse cultural

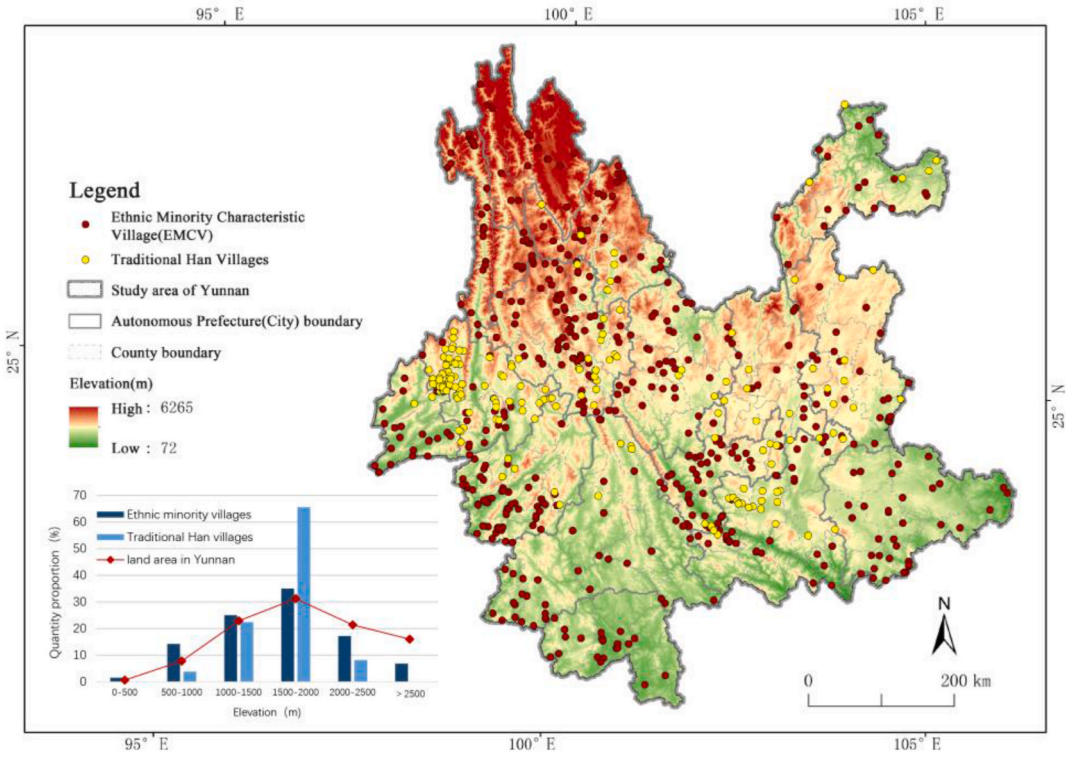


Fig. 10. Distribution of EMCVs and THVs at different elevations in Yunnan.

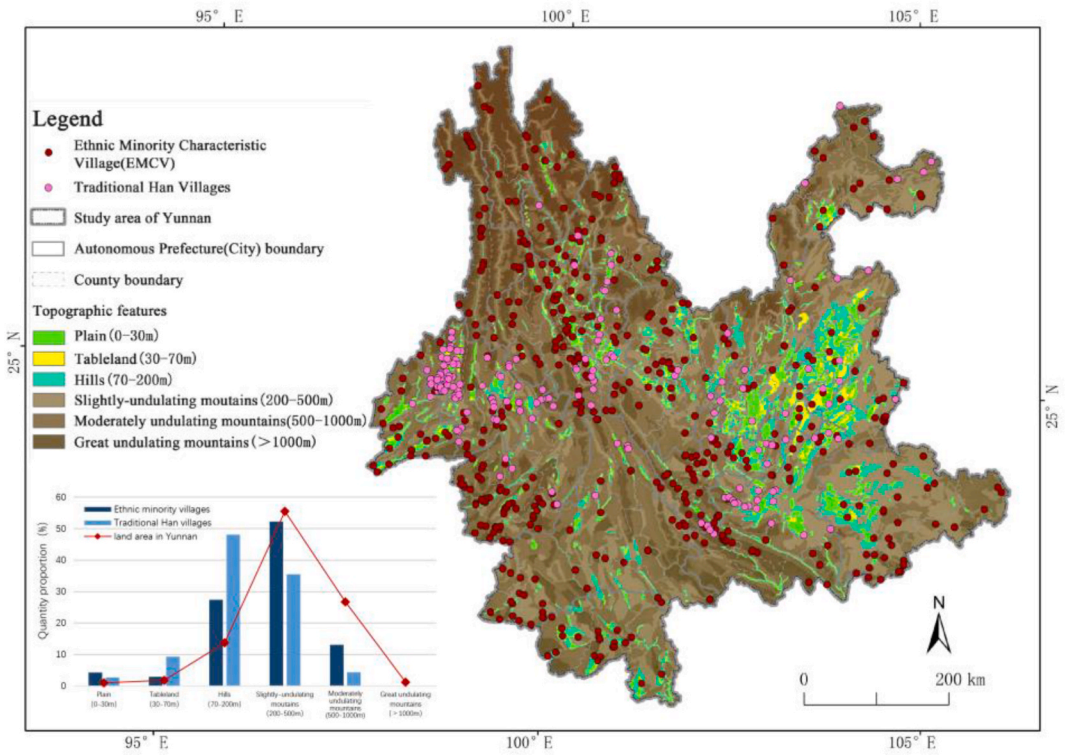


Fig. 11. Distribution of EMCVs and THVs in different topography.

Table 4
The average distance between EMCVs of different ethnic groups and their nearest rivers (Km) .

Tibetan	Pumi	Naxi	Bai	Lisu	Yi	Hui	Miao	Hani	Bulang	Wa	Lahu	Zhuang	Dai
2.6	2.56	2.46	2.05	1.9	1.8	1.75	1.6	1.5	1.4	1.39	1.38	1.05	0.89

landscapes as "different customs within a hundred miles". This is not only an adaptation of various ethnic groups to the natural environment and cultural ecology but can also reduce conflicts among different ethnic groups due to differences in resource utilization, ideology, and patriarchal nature. This distribution pattern is also mutually confirmed by the relationship between the EMCVs and river systems mentioned above, highlighting the differences in distribution caused by the traditional livelihood cultures of different ethnic groups.

4.2. Social and humanistic factors

4.2.1. Population

As the carrier of production and life for the majority of the ethnic minority population, the distribution pattern of EMCVs is closely related to the historical development pattern of ethnic population. This pattern resulted from migration, conflicts, differentiation, and integration of various ethnic groups in Yunnan over thousands of years. According to the relevant data of the 2020 Statistical Yearbook of Yunnan Province, there are 16.309 million ethnic minorities distributed in 16 prefectures (cities) in Yunnan Province, accounting for 33.6% of the total population of the province.

The correlation analysis between the population of each ethnic minority and the number of EMCVs was carried out (Fig. 12). The value of R^2 is 0.87, indicating a high correlation: ethnic groups with larger populations have a larger number of corresponding EMCVs. Ethnic groups that were numerically dominant had stronger national combat effectiveness, making it easier to establish independent economic regions and cultural centers during historical evolution. For example, the Dai, Yi, and Bai nationalities successively established historical dynasties, such as the Mengmao Ancient Kingdom, the Nanzhao Kingdom, and the Dali Kingdom, during the history of Yunnan. This led to the creation of splendid cultures and formation of many settlements with a certain scale that could display their customs and national culture.

On the other hand, the analysis result shows that the correlation between the number of ethnic minority populations in various prefectures (cities) and the number of EMCVs (Fig. 13) is low (R^2 is 0.18). This may be due to the correlation between the declaration and evaluation of EMCVs and the work systems and leadership attention of various administrative units.

4.2.2. Distance from central city

Central cities have important advantages in economic activities and resource allocation and have a certain pulling effect on their peripheral cities and the entire regional economy [50,51]. However, previous studies found that the development radiation brought by central cities may have a certain impact on the survival of traditional cultural heritage, with areas further away from the central city possibly retaining more traditional villages [32,37,41]. In order to clarify the impact of the development of central cities on the distribution of EMCVs in Yunnan, this paper calculated the distances from the EMCVs and THVs to their closest central cities (Fig. 14(a and b)). The result presents a normal distribution with a peak value at the distance of approximately 68–85 km. As the distance from the central city increases, the number of EMCVs increases within 75 km and then decreases beyond that. There is only sporadic distribution beyond 150 km from central cities. Overall, a large proportion of EMCVs (75%) are distributed within 40–120 km. Relatively speaking, THVs are located at a peak distance of 59–67 km from the central city, while the vast majority (84%) are located between 32 and 85 km, showing that EMCVs and THVs in Yunnan are mostly located at a moderate distance from the central city. Due to the limited influence from the city and transportation challenges, these villages have developed a strong isolation mechanism, allowing them to preserve their ethnic culture more completely. This isolation, however, does not lead to a lack of sustainable development vitality or a rapid decline, as they are not too far away. Compared to traditional villages of the Han nationality, EMCVs are distributed in more remote areas, especially in areas 80 km away from central cities. EMCVs have more than 1/3 of the population

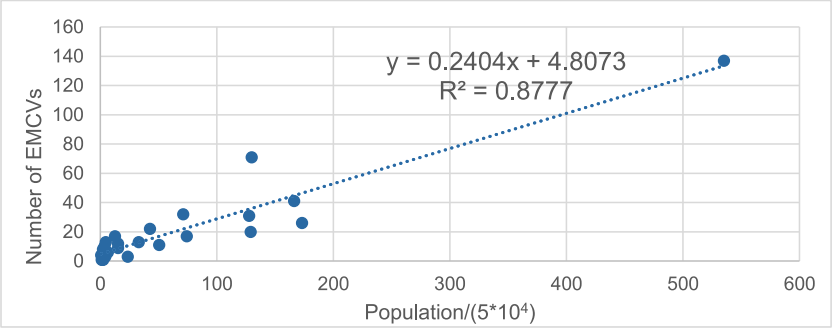


Fig. 12. Scatter chart of population and EMCVs of each ethnic group.

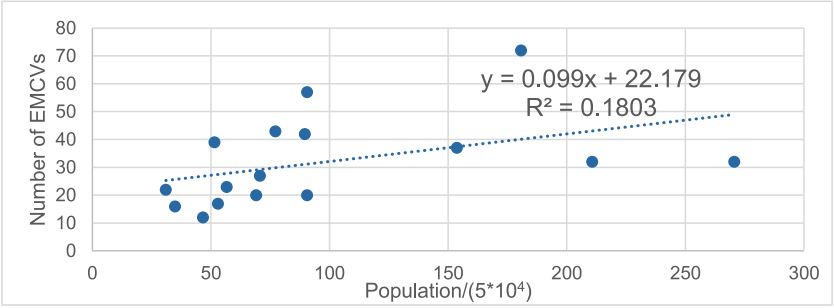
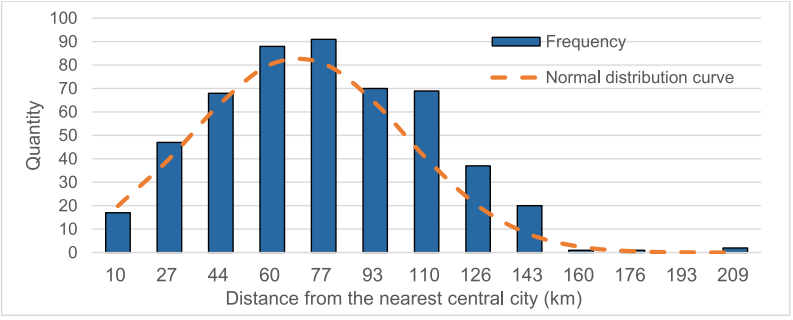
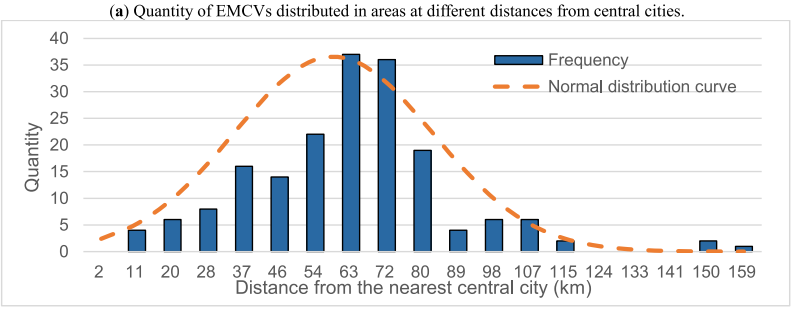


Fig. 13. Scatter chart of the ethnic minority population and EMCVs in each prefecture (city).



(**a**) Quantity of EMCVs distributed in areas at different distances from central cities.



(b) Quantity of THVs distributed in areas at different distances from central cities

Fig. 14. Quantity of EMCVs and THVs distributed in areas at different distances from central cities: (**a**) EMCVs, (b) THVs.

distribution (37.9%) beyond 80 km, while THVs have only 11.5%.

The normal distribution in terms of distance from the central city indicates a moderate location pattern with the central city in the maintenance of EMCVs. Being too close to the city will have a certain impact on the survival of ethnic characteristics, leading to changes in traditional scenes, the disappearance of local and ethnic characteristics, and other issues. On the other hand, being in too remote areas may lower development vitality and increase population loss, further leading to the demise of EMCVs.

Further statistics were conducted on the average distance between different ethnic villages (with a quantity greater than 10) and their adjacent central cities. The results showed significant differences among different ethnic groups (Table 5). Among them, the average distance between Wa villages and their adjacent central cities was the farthest, at 96 km, while the one of Hui villages was the closest, at only 44 km. Based on the analysis of nuclear density distribution and terrain overlap in previous texts, it can be seen that the distribution of ethnic minority villages such as Wa, Zhuang, Hani, and Lahu have significant marginal and mountainous characteristics, and is less influenced by Han culture and modernization process. For example, the Wa group, one of the "Ethnic groups with cross-stage development"[8] in Yunnan, is distributed in remote areas with limited transportation, and still inhabits the most primitive "chicken cage" style stilt dwellings in Yunnan, preserving the original firepit culture and natural worships. The Hui, Naxi, Bai, and Yi villages that are closer to the central city are generally distributed in areas with relatively flat terrain and better transportation conditions. These areas also experienced fierce ethnic integration and cultural exchanges. For example, the Hui group predominantly resides in the center of small basins similar to the Han group, and their culture, residence, and lifestyle have also undergone significant

[8] Refers to the ethnic groups that directly transitioned from a primitive society to a socialist society without democratic reform after the founding of the People's Republic of China.

Table 5
The average distance between EMCVs of different ethnic groups and their nearest rivers (km) .

Wa	Zhuang	Hani	Lahu	Dai	Miao	Lisu	Pumi	Bulang	Yi	Tibetan	Bai	Naxi	Hui
96	90	85	84	71	70	68	68	63	61	55	54	47	44

sinicization.

4.2.3. Local socio-economic development level

In order to further explore the relationship between the distribution of EMCVs in Yunnan and the local socio-economic level, five indicators of socio-economic factors were included in the analysis, including per capita GDP of each county, per capita disposable income of rural permanent residents, and the gross annual output values of primary industry, secondary industry, and tertiary industry.[9] The data for these indicators comes from the 2020 Statistical Yearbook of Yunnan Province. Using the average values of the whole province, counties containing EMCVs, counties containing more than 10 EMCVs, counties containing THVs, and counties containing more than 10 THVs as measurement and comparison units, statistical analysis is conducted on the relationship between the distribution of EMCVs and various indicators of local socio-economic development, as well as the differences between EMCVs and THVs (Fig. 15).

The statistical results show that for the indicators including per capita GDP, primary industry, secondary industry, and tertiary industry, the average value of counties containing more than 10 EMCVs is lower than that of counties containing EMCVs, and the average value of counties containing EMCVs is lower than the average value of the whole province, showing a certain negative correlation. In general, the per capita disposable income of regions that retain a large number of EMCVs is roughly equal to the provincial level, but both the per capita GDP and the GDP of each industry are relatively low, especially in the secondary and tertiary industry indicators, which are far lower than the provincial average and the average of EMCV distribution areas. From the previous analysis, it can be seen that 65.36% of EMCVs are located in mountainous areas. Due to the narrow and barren land, development is difficult, which to some extent restricts the urbanization process. In addition, by comparing various economic indicators of THVs, it can be found that various economic indicators of THVs in Yunnan are higher than those of EMCVs. Some indicators, such as per capita income and primary and secondary industries, are even higher than the provincial average, reflecting that THVs have a better economic foundation.

4.3. Comprehensive impact factor analysis

Based on the above univariate analysis, 11 factors including river distance, river grade, elevation, topographic relief, ethnic population, distance from the central city, per capita GDP, disposable income, and the gross annual output values of primary industry, secondary industry, and tertiary industry are selected as the correlation variables affecting the spatial distribution of EMCVs in Yunnan.

Referring to the practice of other studies of the same type, the values of the correlation variables are discretized [35,36,52] and divided into five grades by naturally clustering in ArcGIS10.7. The national population is based on data at the state (city) level, while factors such as per capita GDP, disposable income, primary industry, secondary industry, and tertiary industry are based on county-level data. Although this cannot directly reflect the individual development differences of EMCVs, it can reflect the development status of ethnic villages within each county to a certain extent.

The comprehensive impact of various factors on the overall distribution of EMCVs in Yunnan is measured by the differentiation and factor detection in Geodetector, which is used to indicate to what extent each independent variable explains the spatial differentiation of the dependent variable, i.e., the quantity of EMCV (Table 6). Among the 11 factors included in the statistics, 9 factors reached a significant level of correlation with EMCV.

As can be seen in Table 6, the topographic relief, distance from rivers, and altitude have the greatest correlation with the spatial distribution of EMCVs. Yunnan itself is a mountainous region with complex and diverse terrains. Under the influence of ethnic history and policies, ethnic minorities mainly live in mountainous areas with traditional agriculture and animal husbandry as the main livelihood models, relying heavily on water sources. Combining with the previous single-factor analysis, it can be seen that there are significant differences in the relationship between different ethnic groups and the geographical factors that have the greatest impact on the overall distribution of EMCV. As pointed out earlier, the different relationships with topography and hydrology are related to ethnic origin culture, including the type of ethnic from which they originated and differentiated, as well as the characteristics of livelihood culture. Therefore, geographical elements mainly provide a diversified spatial framework for the migration and distribution of multiple ethnic groups in Yunnan, which is also a fundamental condition for the coexistence of diverse cultures. Therefore, the protection of native environmental elements may be of great significance for the survival of Yunnan's multi-ethnic culture and villages.

[9] According to the regulations of the National Bureau of Statistics of China, the primary industry refers to agriculture, forestry, animal husbandry, and fishery (excluding agricultural, forestry, animal husbandry, and fishery service industries); the secondary industry refers to the mining industry (excluding auxiliary mining activities), manufacturing industry (excluding metal products, machinery and equipment repair industry), electricity, heat, gas and water production and supply industry, and construction industry; and the tertiary industry, also known as the service industry, refers to industries other than the primary and secondary industries.

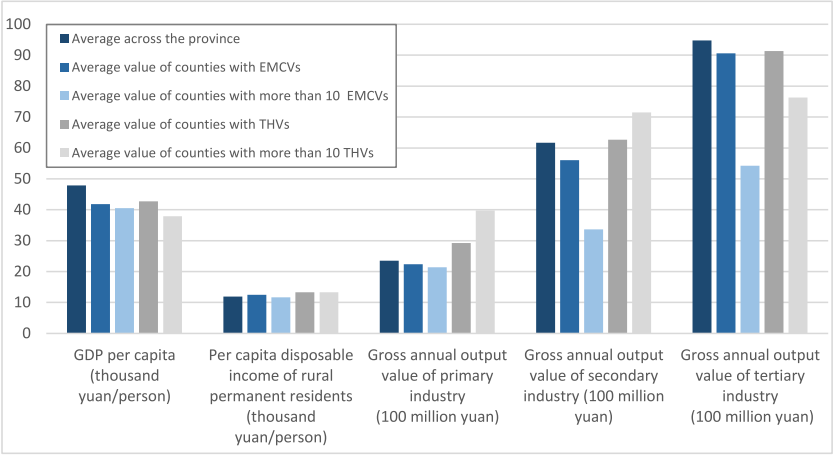


Fig. 15. Relationship between socioeconomic development and the quantities of EMCV and THV in Yunnan.

Among the human factors, except for the ethnic population directly related to the survival of EMCVs, the impact of other factors is relatively small. The narrow living space in mountainous area restricts the development of social economy, especially the inconvenient transportation and distance from the city, making the village less affected by the urbanization process, and objectively providing natural conditions for the village's survival to some extent. However, based on the previous single-factor analysis of urban distance, it can be seen that the relationship between the survival of EMCVs and cities may not be unidirectional (i.e., the farther the better, or vice versa). Instead, it requires maintaining a moderate location pattern so that they can obtain a certain degree of development impetus while preserving their ethnic characteristics and avoiding excessive homogenized by modern culture.

5. Conclusion and limitation

The study of the spatial distribution characteristics of EMCVs is essentially a discussion of the generation and survival of EMCVs. This article takes 511 national and provincial EMCVs in Yunnan Province as the research object. Firstly, it analyzes the spatial distribution characteristics of EMCVs in Yunnan such as distribution density and autocorrelation. It then analyzes the relevant factors for the formation and continuation of EMCVs from natural, historical, and economic aspects. In response to the characteristics of multi-ethnic integration in Yunnan, a special comparative analysis was conducted on the distribution characteristics of settlements among different ethnic groups and their correlation with natural, cultural, and geographical factors.

1) The overall spatial distribution of EMCVs in Yunnan has the characteristics of cohesion and positive spatial correlation, with a significant imbalance in distribution, showing a structural feature of "three regions and multiple scattered points" and a distribution pattern of "hot spots in the west and cold spots in the east". From the perspective of ethnic differences, the distribution of EMCVs shows significant ethnic autocorrelation, that is to say, each ethnic group has relatively concentrated region, among which Yi, Miao, and Dai have multiple clusters.
2) Natural and geographical conditions such as topographic relief, river distance, and altitude are the main factors affecting the distribution pattern of EMCVs, which tend to be distributed in high-altitude areas near low-level rivers. On the other hand, the correlation analysis with social factors shows that the development of social economy and the promotion of urbanization bring challenges to the preservation of ethnic villages. EMCVs are relatively more likely to remain in places with less urban radiation and underdeveloped economies, but it is worth noting that there is a moderate location pattern in terms of the distance from the central city in the maintenance of EMCVs.
3) In the overall comparison between EMCV and THV, the latter tends to occupy more hilly areas with better farming and construction conditions, reflecting the deficiency of the basic living conditions of EMCVs. Among various ethnic groups, the relationship between EMCVs and geographic environment in terms of river systems and topography presents certain differences, which is found to be significantly related to differences in ethnic origin and livelihood culture. The terrain of Yunnan, which is fragmented into various scattered small geographical units by high mountains and big rivers, has also promoted the isolation and differentiation of various ethnic groups after immigration. Multiple ethnic minorities have formed a spatial distribution pattern of "intermingled in macro-region and clustering in micro-region" in horizontal geographical space and vertical three-dimensional distribution.

In general, the spatial distribution pattern of EMCVs in Yunnan is the result of the combined effects of the natural and cultural environment. The rich and diverse terrain, profound historical culture, and diverse ethnic composition promote the formation of EMCVs, forming a special multidimensional distribution pattern. However, under the fundamental pattern formed by geography and history, the survival of EMCS today is affected more by the impact of urbanization development. Notably, in the context of China's Rural Revitalization Strategy and the Belt and Road Initiative, rural modernization has gradually broken through the physical and

Table 6
The degree of influence of multiple factors on the distribution of EMCVs based on Geodetector.

Detection factor	Topographic relief	Distance from river	Altitude	Ethnic population	Disposable income	Nearest river grade	GDP per capita	The secondary industry	Distance from central city	Tertiary industry	Primary industry
q	0.65*	0.49**	0.32*	0.23**	0.22	0.20**	0.19*	0.18*	0.18**	0.15	0.12**

Note: *, **, and *** are significant at the level of 10%, 5%, and 1%, respectively.

geographical separation, and the influence of social, economic, cultural, and other human factors on the future survival of EMCVs will become increasingly prominent.

However, due to the reliance on data statistics, this study is mainly limited by two factors, which will be the focus of future research: 1) The acquisition of social and humanistic information is relatively limited and essentially based on county-level, with a lack of information on townships or village levels, making it insufficient to deeply analyze the specific characteristics of different villages. Similar issues have also appeared in similar studies [32,35]. Future research is to improve accuracy and depth by conducting in-depth investigation of smaller partitions of Yunan step by step by narrowing the scope of the study. After sufficient partition accumulation, further macroscopic comparisons and inductions can be attempted. 2) Some ethnic groups have too few samples at present and are not statistically significant to support universal statistics. In future research, efforts will be made to expand the sample size of one or several major ethnic groups and further explore ethnic characteristics or differences.

Data availability statement

All data in this article are from an open official database (marked in the main text and footnotes), except for the ethnic attributes of each ethnic village, which was applied from the Ethnic and Religious Affairs Commission of Yunnan Province and Ethnic and the Religious Affairs Bureau of autonomous cultures (cities) in Yunnan Province, but without permission for secondary dissemination and sharing. The directory of Ethnic Minority Characteristic Villages of Yunnan with precise location coordinates can be made available from the corresponding author upon reasonable request.

CRediT authorship contribution statement

Wenjing Gao: Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Xiaolan Zhuo:** Writing – review & editing, Validation, Supervision, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Dawei Xiao:** Resources, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Xiao Dawei reports financial support was provided by National Natural Science Foundation of China (51778232). Zhuo Xiaolan reports financial support was provided by Guangdong Basic and Applied Basic Research Foundation (2023A1515011702). If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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