



Analysis of the spatial distribution and influencing factors of China national forest villages

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Received: 21 November 2021 / Accepted: 2 May 2022 / Published online: 13 May 2022
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Abstract China national forest villages are the agents to promote rural greening and beautification, as well as further implementation of the rural revitalization strategy. It is of great significance to study their spatial distribution characteristics and influencing factors. Therefore, taking 7586 China national forest villages as examples, the methods of nearest neighbor index, Tyson polygon, cold and hot spot analysis, and nuclear density index are used to study the spatial distribution characteristics of China national forest villages and their influencing factors. The results show that (1) since the nearest neighbor

index is less than 1, and the Tyson polygon area variation coefficient is much greater than 64%, it is comprehensively determined that the distribution of China national forest villages belongs to agglomerated distribution. (2) The spatial clustering is characterized by “hot in the south and cold in the north.” The hot spots are dominated by southern regions such as Sichuan, Hubei, and Jiangsu, and the cold spots are dominated by northern regions such as Heilongjiang, Jilin and Xinjiang. (3) The distribution characteristics of nuclear density have a strong correlation with the distribution characteristics of forest vegetation and urban agglomerations. Most high-density areas are located within the forest vegetation coverage. The first batch forms the Yangtze River Delta and Central Plains urban agglomerations high-density areas, and the second batch forms the Yangtze River Delta and Central Plains high-density areas. (4) Elevation, aspect, river, forest resources endowment, traffic, economic development level, and population size are important factors affecting the distribution of China national forest villages, and their distribution presents the characteristics of “low altitude, positive direction, near water, rich forest resources, convenient transportation, developed economy, and dense population.” The research can provide reference for the evaluation and construction of China national forest villages and the implementation of village beautification and rural revitalization strategies in the future.

Supplementary information The online version contains supplementary material available at <https://doi.org/10.1007/s10661-022-10087-8>.

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Keywords Forest resources · Landscape pattern · GIS · Correlation analysis · Rural revitalization

Introduction

Rural revitalization is an effective strategy for promoting the sustainable and healthy development of rural areas in developing countries (Yang et al., 2021a). Ecological living environments are the primary issue of rural revitalization, which requires the construction of beautiful and livable villages and the promotion of green rural development (Bu et al., 2020). The construction of national forest villages as an innovative measure to cultivate a rural ecological greening economy directly affects the process of rural living environment governance and rural revitalization. China national forest villages refer to the administrative villages that are organized and guided by the National Forestry and Grassland Administration. China national forest villages take “prosperous industry, ecological livability, civilized rural customs, effective governance, and affluent life” as the general requirements. Through a comprehensive evaluation, certain quantitative indicators and evaluation methods and standards are used to determine that villages’ greening and beautification can meet the evaluation standards. China national forest villages are characterized by well-preserved rural natural ecological features, prominent rural pastoral features, strong forest atmosphere, significant forest function benefits, good development of forest-related industries, clean living environment, and effective protection and management (Chen et al., 2021). The national forest village is one of the most important types of villages. It is not only a new model for the protection and sustainable development of forest resources, but also an important resource for rural revitalization. However, with the acceleration of urbanization, the living space of forest villages is invaded and the ecological environment destroyed. In order to better protect national forest villages, the National Forestry and Grassland Administration in China has published a list of the first two batches of national forest villages. With the national forest villages as the lead, China will gradually develop local forest villages and national demonstration counties of rural greening and beautification, drive all villages to jointly promote rural greening and beautification, and, finally, realize the strategy of rural revitalization.

The rural area is the smallest settlement unit, and rural development has always been the focus of academic circles. The study of rural geography began in

the first half of the nineteenth century. Kohl (1841) made a systematic study of settlements. Brunhes (1921) made a comprehensive study of the relationship between rural settlements and the environment, establishing many basic principles of rural settlement geography. Currently, studies on rural areas are focused mainly on rural communities (Barraket et al., 2019; Rivera-Arriaga et al., 2021), rural landscape (Agnoletti, 2014; Cillis et al., 2020), balanced urban–rural development (Tang et al., 2021; Xi et al., 2015), rural tourism management and operation (Cunha et al., 2020; Lane, 1994), and protection and inheritance of rural culture (Gupta, 2005; Ye et al., 2020). The forest is an important resource that can affect social, cultural, and ecological functions (Sasaki & Putz, 2009). The countryside is an important carrier of forests, so studying forest villages plays a great role in protecting forest resources and revitalizing the rural areas. At present, relevant studies focus mainly on rural forest tourism, rural greening, and other themes. For example, Ohe et al. (2017) believes that forest–therapy tourism, as an emerging type of rural tourism, expands the market of rural tourism. Balezentis et al. (2020) takes Lithuania as an example to investigate the impact of the support system for young farmers on rural greening and sustainable development. Kou et al. (2021) quantitatively evaluated the relationship between human activities and rural greening. Secondly, rural forest land use and the relationship between rural and forest have also attracted the attention of scholars. Appiah et al. (2016) studied the impact of reducing emissions from deforestation and forest degradation with other benefits (REDD+) mechanism on rural forest land and climate change. Kurowska et al. (2020) studied the impact of farmland and forest protection on spatial planning in Poland and predicted future land use types. In terms of the relationship between forest and rural areas, Nguyen and Tran (2018) studied the relationship between forest resources and rural households’ livelihood and found that forest income is the second biggest factor causing income inequality of rural households; Angelsen et al. (2020) investigated the impact of migration and remittances on forest cover in eight rural areas in Guatemala and Chiapas, Mexico; and Dong et al. (2020) discussed the impact of China’s forestland mortgage policy on rural farmers’ access to credit and found that the existing policy increased rural farmers’ credit channels to a certain

extent. There are few studies related to national forest villages. Only Zheng et al. (2021a), Yang et al. (2021c) and Hou et al. (2021) explored the spatial distribution, type characteristics, and influencing factors of national forest villages.

The rural revitalization strategy is one of the strategies that China attaches great importance to and is also a persistent hot topic in academic circles. As a typical representative of rural greening and beautification, China national forest villages are “new” villages that have further implemented the rural revitalization strategy. However, there has not been a large number of research results taking China national forest villages as research objects. In view of this, this paper takes 7586 China national forest villages as examples, and uses the nearest neighbor index, Tyson polygon, cold and hot spot analysis, and nuclear density index to study their spatial distribution characteristics and influencing factors.

The main contributions of this paper are as follows: (1) It hopes to enrich the research object and content of rural geography theoretically, and deepen the understanding of the factors affecting the spatial distribution of national forest villages. This is a new progress in the theoretical study of beautiful village construction in China. (2) It can provide a theoretical basis for optimizing the spatial layout of national forest villages, rational protection and sustainable development of rural forest resources, and provide decision-making reference for the construction of rural ecological civilization and rural revitalization. (3) China is a developing country with abundant forest resources. This study can provide references for other countries in the world in ecological protection, construction, and beautification of rural areas.

Research methods and data sources

Research methods

This paper adopts the framework of firstly an overall analysis and then gradually a detailed analysis to study the spatial distribution characteristics of China national forest villages. First, the overall distribution type is judged, then the distribution of cold and hot spots in specific provinces, and, finally, the distribution characteristics of specific high and low density areas, so that a more comprehensive spatial distribution characteristic

can be gained. For the results obtained, the influencing factors of forming this spatial distribution pattern are further explored. The research methods of spatial distribution characteristics draw lessons from the research results of Li (2019), Yang et al. (2021b), Zheng et al. (2021b) and Zuo et al. (2021), and adopt the nearest distance, Tyson polygon, hot spot analysis, and nuclear density analysis from the three angles of type, hot spot, and density, respectively. The research methods of influencing factors refer to Şener et al. (2011), which adopt buffer analysis and superposition analysis.

Nearest neighbor index

In 1954, Clark and Evans (1954) first proposed the nearest neighbor analysis method and applied it to analyze the spatial distribution characteristics of populations, but the method at that time was not perfect and mature enough, and, later, the scholars Pinder and Witherick (1973) improved it. The nearest neighbor analysis method gradually developed into a mature method that can study the distribution type of arbitrary spatial point-like elements.

China national forest villages can be macroscopically regarded as point elements. There are three kinds of distribution of points, namely uniform, random, and condensed distribution. The distribution characteristics of points can be analyzed by using the nearest neighbor index R , which is a geographical index representing the degree of proximity between points (Pearce & Tan, 2006). Its formula is as follows:

$$R = r_1/r_E \tag{1}$$

$$r_E = 1/2\sqrt{n/A} \tag{2}$$

where r_1 represents the closest distance in practice, r_E represents the closest distance in theory, n represents the total number of research objects, and A represents the area of the research region. When $R > 1$, the distribution is uniform. When $R = 1$, the distribution is random. When $R < 1$, the distribution is a condensed distribution.

Tyson polygon

The standard of the nearest neighbor index used to judge the spatial distribution of point-like elements is still controversial. In order to ensure the accuracy of determining

the spatial distribution type of China national forest villages, the method of calculating the coefficient of variation of the area of the Tyson polygon is used for testing. Since the area of Tyson polygon changes with the degree of point-like elements agglomeration, the coefficient of variation calculated based on the area of Tyson polygon can be used to determine the spatial distribution type of the research object. The coefficient of variation formula is:

$$CV = \frac{R}{S} \times 100\% \quad (3)$$

where R represents the standard deviation of the area of Tyson polygon and S represents the average value of the area of Tyson polygon. Zhou et al. (2017) pointed out that when $CV = 57\%$ (including 33–64%), the point-like elements were randomly distributed. When $CV = 92\%$ (including > 64%), the point-like elements are condensed distribution. When $CV = 29\%$ (including < 33%), the point element is uniformly distributed.

Hot spot analysis

Hot spot analysis is a comprehensive analysis of the elements themselves and the surrounding elements. The so-called hot spot refers to the element itself, which has high value, and every element in the surrounding element environment, which also has high value at the same time. By calculating the statistics of Getis–Ord G_i^* for each element in the data set, the spatial clustering location of high and low value elements was determined based on the obtained z -score and p -value (de Moura & Procopiuck, 2020). Its formula is:

$$G_i^* = \frac{\sum_{j=1}^n W_{ij} X_j - \bar{x} \sum_{j=1}^n W_{ij}}{\sqrt{\frac{s}{n-1} \left(n \sum_{j=1}^n W_{ij}^2 - \left(\sum_{j=1}^n W_{ij} \right)^2 \right)}} \quad (4)$$

where n represents the total number of elements, x_j represents the attribute value of element j , w_{ij} represents the space weight between element i and j , and:

$$\bar{X} = \frac{\sum_{j=1}^n X_j}{n}; S = \sqrt{\frac{\sum_{j=1}^n X_j^2}{n} - (\bar{X})^2} \quad (5)$$

The G_i^* statistic returned for each feature in the dataset is a z -score. For positive z -scores with prominent statistical significance, the higher the z -score is, the tighter the clusters of high values (hot spots) will be. For negative z -scores with prominent statistical significance, the lower the z -score is, and the tighter the clustering of low values (cold points) will be.

Kernel density analysis

The kernel density estimation method uses the spatial distribution of point density to reflect its aggregation status. Each grid dot is taken as a center to search the circular area with a certain radius, and the point elements falling into the circular area are counted and given different weights to the point elements. The closer the point elements are to the center, the greater the weight of the point elements is, and then the grid dot density is calculated (Xia & Yan, 2008). Its formula is:

$$f(x) = \frac{1}{nh} \sum_{i=1}^n k\left(\frac{x-x_i}{h}\right) \quad (6)$$

where n represents the coordinate points, h represents the bandwidth, k represents the kernel function, x_i represents the coordinates of point i , and $(x-x_i)$ represents the distance between two points. The larger $f(x)$ is, the denser the distribution is. The ArcGIS 10.3 software kernel density analysis tool was used to analyze the core density of China national forest villages, and the kernel density index was divided into five sections from high to low according to the natural discontinuous point classification method.

Spatial overlay analysis

Spatial overlay analysis is a basic method for succinctly analyzing spatial correlation. It mainly combines multiple (two or more) layer features to create a new feature layer (Zhang et al., 2021), and contains the analysis of previous layer features. In this paper, the spatial location information of China national forest villages is superimposed with a digital elevation model (DEM), terrain, rivers, traffic and other factors, and the influence of each factor on the spatial distribution of national forest villages is further clarified.

Pearson correlation coefficient

The Pearson correlation coefficient is a method to examine the correlation between variables (Shuai et al., 2018). This study applied the Pearson correlation coefficient to test whether there is a certain correlation between the spatial distribution of China national forest villages and its related influencing factors. The Pearson correlation coefficient between two factors (x, y) is formulated as follows:

$$R_{xy} = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2} \sqrt{\sum_{i=1}^n (y_i - \bar{y})^2}} \quad (7)$$

where \bar{x} and \bar{y} represent the average value of x and y , respectively, and x_i and y_i are the individual sample points indexed with i .

Data sources

The selected list of 7586 China national forest villages in the first and second batches was obtained from the official website of the National Forestry and Grassland Administration (www.forestry.gov.cn), and its geographic coordinates were obtained through the Baidu coordinate picker. The administrative boundary was extracted from the 1:400,000 map database of the National Geomatics Center of China (www.ngcc.cn). The economic and social statistical data were collected from the 2018 Statistical Bulletin and 2019 Statistical Yearbook of 31 provincial administrative units of China (excluding Taiwan Province, Hong Kong Special Administrative Region and Macao Special Administrative Region).

Results analysis

Spatial distribution characteristics

Spatial distribution type

The mean nearest neighbor tool in ArcGIS 10.3 was used to analyze the spatial distribution types of China national forest villages, and the spatial distribution type was preliminarily determined according to the nearest neighbor index obtained. The mean nearest neighbor results are shown in Table 1.

It can be seen from Table 1 that $R=0.46 < 1$, so the spatial distribution type of China national forest villages is preliminarily determined as condensed type.

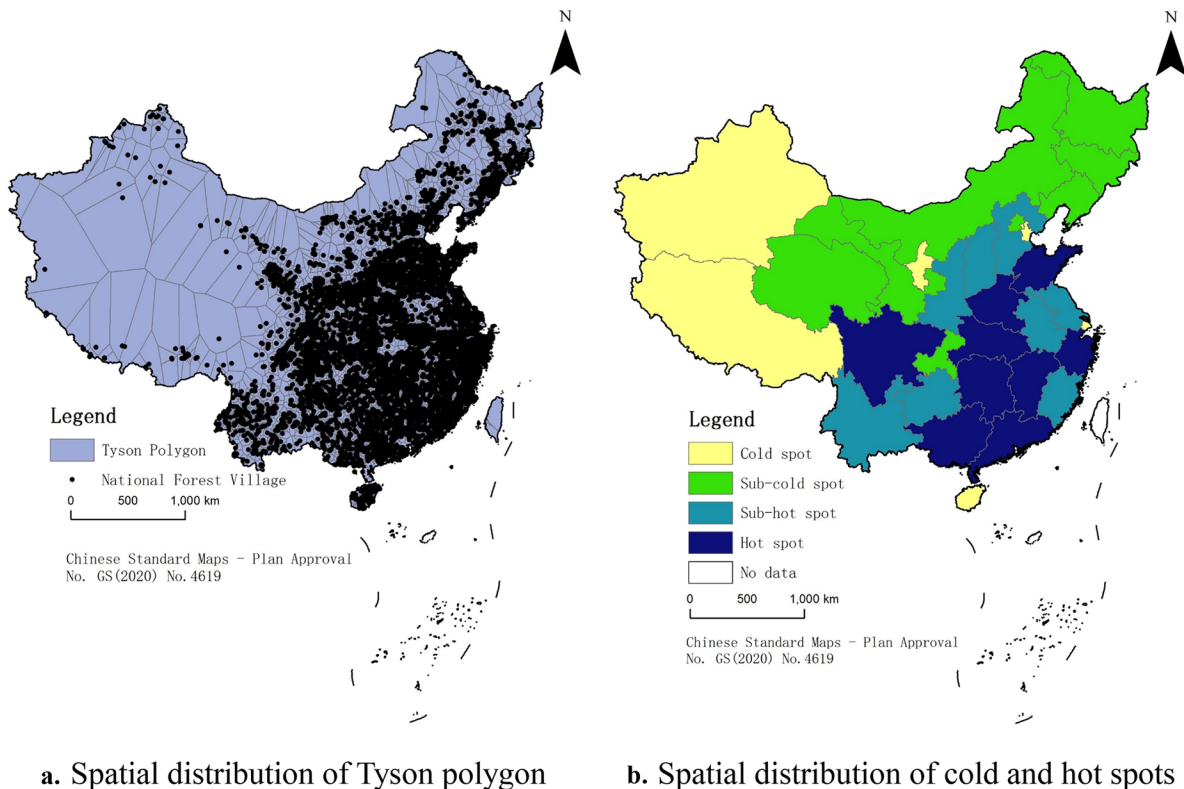
In order to ensure the accuracy of the results, the Tyson polygon method was used to verify the results obtained by the mean nearest neighbor. The Tyson polygon of China national forest village was created by ArcGIS 10.3 (Fig. 1a), and the average area and area standard deviation of the Tyson polygon were calculated. According to the results, $R=8753.9342$, $S=1222.4104$, so $CV=716.12\%$, which is much higher than 64%, indicating that the distribution of China national forest villages is of agglomeration type, and the degree of agglomeration is obvious. Based on the mean nearest neighbor results, the spatial distribution type of China national forest villages can be determined as condensed type.

Cold and hot spot analysis

ArcGIS 10.3 was used to make a spatial connection between China national forest villages and the vector map of China, and then the hot spot analysis was conducted in the spatial statistics tool to make the cold and hot spot map of the spatial distribution of China national forest villages (Fig. 1b). The natural discontinuous point classification method is used to divide z -score into four stages, which are respectively represented as four regions: hot spots, sub-hot spots, sub-cold spots, and cold spots. It can be seen from Fig. 1b that hot spots include nine provinces, namely Sichuan, Shandong, Henan, Hubei, Hunan, Jiangxi, Zhejiang, Guangxi, and Guangdong, accounting for 19.65% of the total area of the country. There are eight provinces (cities) with sub-hot spots, namely Hebei, Shanxi, Shaanxi, Jiangsu, Anhui, Fujian, Yunnan, and Guizhou, accounting for 15.41%. There are also eight provinces (cities) in the sub-cold spots, which are

Table 1 Mean nearest neighbor results for China national forest villages

Project	Value
Average observation distance	10,433.91
Expected average distance	22,682.15
Nearest neighbor ratio	0.46
Z-score	-89.98
P-value	0.00



a. Spatial distribution of Tyson polygon

b. Spatial distribution of cold and hot spots

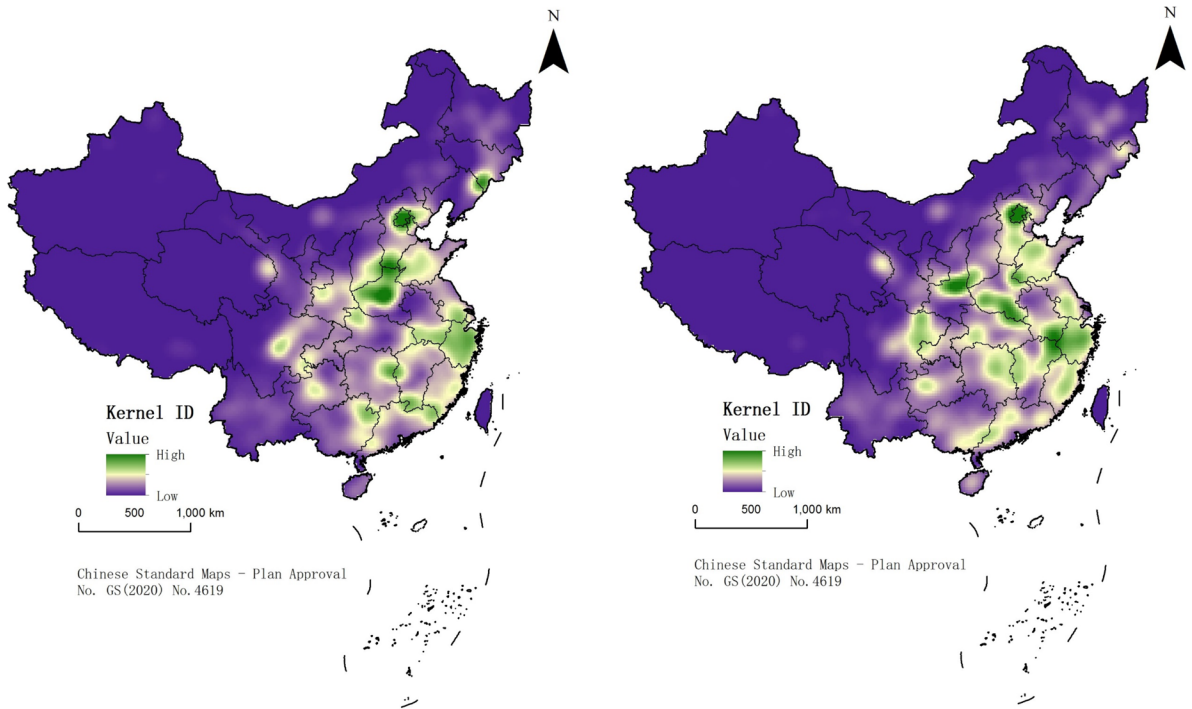
Fig. 1 Spatial distribution characteristics of China national forest villages

Heilongjiang, Jilin, Liaoning, Inner Mongolia, Gansu, Qinghai, Beijing, and Chongqing, accounting for 33.80%. Xinjiang, Xizang, Ningxia, Tianjin, Shanghai, and Hainan are cold spots, accounting for 31.15% of the total. In general, the number of provinces (cities) belonging to hot spots is more than that of cold spots, but in terms of the coverage area, cold spots account for 64.95% of the total area, accounting for more than half of the total area. From the figure, we also can intuitively observe the distribution characteristics of “hot in the south and cold in the north.” The hot spots are mainly concentrated in the south, while most of the northern area is a cold spot area.

Kernel density distribution characteristics

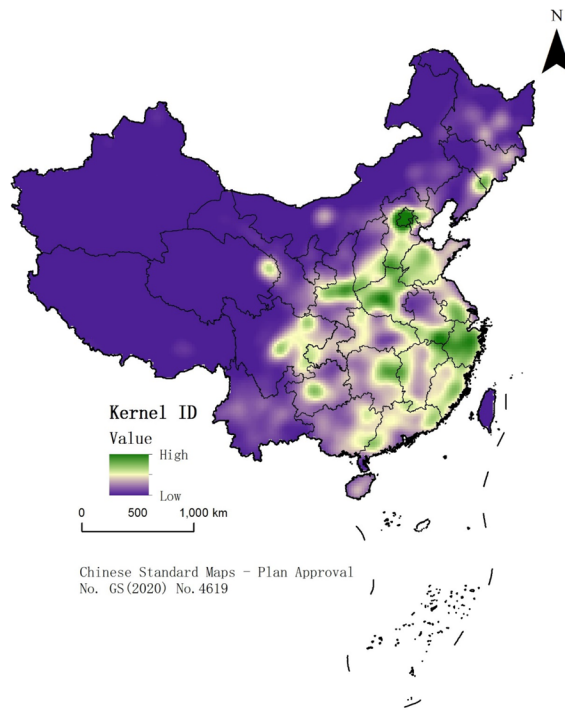
The kernel density function of the ArcGIS 10.3 spatial analysis tool was used to study the spatial distribution density of two batches of China national forest villages, and the results are shown in Fig. 2. According to Fig. 2, the spatial distribution density of China national forest

villages is significantly different, and the characteristics of the two batches of kernel density maps are similar. On the one hand, the density distribution of national forest villages is highly correlated with the vegetation coverage, and almost all the areas with high-density value are located within the forest vegetation coverage, which also conforms to the selection conditions of China national forest villages. On the other hand, it can be found that the distribution of high-density areas is very consistent with that of urban agglomerations. The first batch formed high-density areas in the Yangtze River Delta, Central Plains, Bohai Rim, Pearl River Delta, and middle reaches of Yangtze River and Chengdu–Chongqing sub-density areas, while the second batch formed high-density areas in the Yangtze River Delta, Central Plains, Beijing–Tianjin–Hebei, and Chengdu–Chongqing, as well as sub-density areas in the Pearl River Delta and middle reaches of the Yangtze River. Urban agglomeration, as the core area with the most vitality and potential in the future economic development pattern, is the key and optimized development



a. The first batch of kernel density map

b. The second batch of kernel density map



c. Total kernel density map

Fig. 2 Kernel density map of China national forest villages

zone in the main functional zone strategy. With the support of urban agglomeration construction, villages are often at the leading level in greening and beautification, and the first two batches of China national forest villages are established, thus gradually driving all parts of the country to realize rural greening and beautification.

Influencing factors

Elevation factor

The difference in elevation means that the climate, precipitation, temperature, soil, vegetation, and other conditions are different, and then determines the population distribution, economic development, forest resources, and other factors that directly affect the spatial distribution of China national forest villages. The ArcGIS 10.3 software was used to divide the elevation map of China into five levels according to the natural discontinuous point classification method, and then the elevation was superimposed with China national forest villages to obtain the terrain distribution map of China national forest villages (Fig. 3a), and the number of its statistics are made (Table 2). From Table 2, the higher the level is, the fewer the number of villages will be. Among them, the number of villages with an elevation of (−152)–788 m is 5793, accounting for 76.36%, and the number of villages with an elevation of 789–2092 m is 1572, accounting for 20.72%. The first two levels of villages accounted for 97.08%. Only 2.92% of China national forest villages are located at an elevation above 2093 m, and no villages are found at an elevation between 4,669–8848 m, showing an obvious “low altitude” distribution feature. Low altitudes tend to have flat terrain, developed transportation, and convenient life, which is conducive to population concentration and residence. In addition, due to the low altitude, the moist airflow from the eastern ocean can directly enter the inland and bring abundant precipitation, which is conducive to the cultivation and growth of vegetation. The distribution of vegetation can directly affect the assessment of China national forest villages.

Aspect factor

The aspect is the direction in which the normal of the tangent plane of a point on the slope is projected on

the horizontal plane. The direction is defined as the angle formed by the projection and the true north of the point, so the value range is 0~360°. Different elevations have a huge impact on climate, precipitation, vegetation, temperature, etc., and geographical locations with the same height but different slope directions will also make significant differences. In order to explore the influence of aspect on the distribution of China national forest villages, the elevation map was imported into ArcGIS for aspect analysis, and the obtained aspect map was superimposed with China national forest villages to calculate the number of villages with different aspects, as shown in Table 3. According to Table 3, the slope directions of China national forest villages are diversified due to the complexity of the terrain. Among them, the west slope, northwest slope, and southeast slope are more distributed, with a total proportion of 39.36%, while the north slope and northeast slope are less distributed, accounting for less than 10%. In terms of shady and sunny slopes, the range of sunny slopes is 90–270°, and the shady slopes are 0–90° and 270–360° (Li et al., 2019). Shady and sunny slopes usually need to be analyzed in detail in different regions. In arid and semi-arid areas, the shady slope has a relatively moist soil, so is suitable for the growth of forest trees, while the sunny slope has sufficient sunlight, high water evaporation, low soil moisture, and more grasses. In the south, due to abundant rainfall, the difference in soil moisture between the shade and the sun is not significant. At this time, the sky is sunny and the vegetation coverage density is greater than that of the shade. According to statistics, there are 3764 and 3316 sunny and shaded slopes in China national forest villages, respectively. In terms of quantity, the number of sunny slopes is slightly higher than that of shaded slopes, which is highly correlated with the characteristics of shaded and sunny slopes of southern vegetation.

River factor

Water sources are particularly important for people's daily life, agricultural irrigation, shipping and transportation, and vegetation growth (Li & Jiang, 2018). Rivers are an important source of water. With the second-level river as the center, three levels of buffer zones are made, namely 30 km, 60 km, and 90 km. China national forest villages are superimposed on

Fig. 3 Influencing factors of China national forest villages

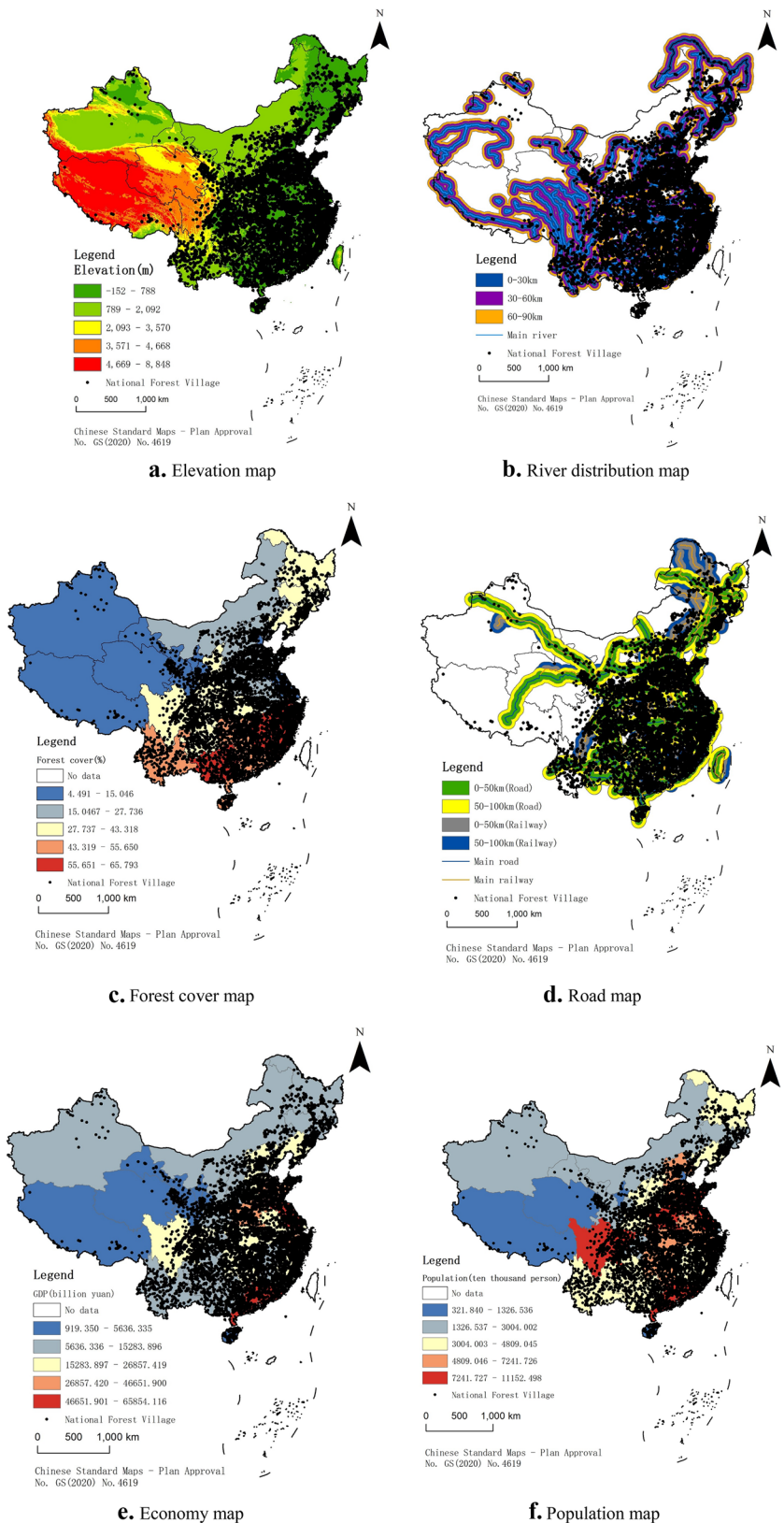


Table 2 China national forest villages' elevation statistics

Grade	Level 1	Level 2	Level 3	Level 4	Level 5
Elevation (m)	(-152)–788	789–2092	2093–3570	3571–4668	4669–8848
Quantity (number)	5793	1572	203	18	0
Proportion (%)	76.36	20.72	2.68	0.24	0

the river buffer zone (Fig. 3b), and the corresponding quantities of each level of buffer zone are calculated (Table 4). According to Table 4, the proportion of China national forest villages within 30 km of the river is 37.66%, the proportion within 30–60 km is 25.73%, the proportion within 60–90 km is 17.18%, and the proportion of China national forest villages within 90 km of the river is as high as 80.57%. In addition, China's topography is high in the west and low in the east, so most rivers flow from west to east. In contrast, the water sources in the central and eastern parts are more abundant than those in the west. According to Fig. 3b, it can be intuitively observed that most villages are located in the middle and lower reaches of rivers. From the above information, most of China national forest villages are distributed around rivers, and the geographical location close to the water source can provide a lot of help for the lives of residents and the development of the village. Pertaining to China national forest villages as a model of rural greening and beautification, it is essential to have river conditions. On the one hand, water sources play a vital role in the development of forestry and rural green coverage. On the other hand, water sources are a necessity for the life of rural residents. Only where there are water sources can people gather to form various unique villages. In addition, the use of rivers can also dig deeper. River resources can often be turned into tourism resources, thereby driving the development of local tourism and promoting rural economic development. In summary, rivers are

an important factor affecting the spatial distribution of China national forest villages.

Forest resources endowment factor

China national forest villages are villages with forest resources as the main body, and the rural greening and beautification meet the evaluation standards. The forest cover is an important indicator that reflects the abundance of forest resources and ecological balance. Using ArcGIS 10.3 software, the average of forest cover in each region from 2006 to 2020 was divided into five levels according to the natural discontinuous point classification method, and then the forest cover was superimposed with China national forest villages to obtain the overlay map of forest cover (Fig. 3c). From Fig. 3c, it can be found that the provinces with high forest cover also have more villages. For example, Fujian, Jiangxi, Zhejiang, and Guangxi have the highest forest cover, and the number of national forest villages is also in the forefront. Provinces with a forest cover higher than 30% have 5009 villages, accounting for 66.03%. In addition, the average value of forest cover in each province from 2006 to 2020 was selected for correlation analysis with the number of China national forest villages in each province. It can be seen that at the 99% confidence level, the Pearson correlation coefficient between the number of China national forest villages and forest cover is 0.537, indicating that there is a significant positive correlation between the distribution of China national

Table 3 China national forest villages slope statistics

Aspect	North slope	Northeast slope	East slope	Southeast Slope	South slope	Southwest slope	West slope	Northwest slope
Angle range (°)	0~22.5, 337.5~360	22.5~67.5	67.5~112.5	112.5~157.5	157.5~202.5	202.5~247.5	247.5~292.5	292.5~337.5
Quantity (number)	689	758	863	987	863	970	1004	995
Proportion (%)	9.08	9.99	11.38	13.01	11.38	12.79	13.23	13.17

Table 4 Statistics of distances between China national forest villages and rivers

Grade	Level 1	Level 2	Level 3	Total
Distance (m)	0–30 km	30–60 km	60–90 km	90 km
Quantity (number)	2857	1952	1303	6112
Proportion (%)	37.66	25.73	17.18	80.57

forest villages and forest coverage. To summarize, forest resource endowment is an important factor affecting the spatial distribution of China national forest villages. The selection of China national forest villages fully takes into account the local forest resources.

Traffic factor

Accessibility has an important impact on all aspects of the village, such as the spread and promotion of rural traditional culture, the quality of life of residents, the influence of the outside world on it, the degree of rural greening, and the level of economic development. The accessibility of villages is directly determined by the degree of traffic development. Therefore, the buffer zones with a distance of 50 km and 100 km are made with the main roads and railways as representatives, which are superimposed with China national forest villages to obtain the distribution map of China national forest villages transportation network (Fig. 3d), and the number of villages in the buffer zones with different distances is counted, as shown in Table 5. According to Table 5, 83.42% of China national forest villages are located within 100 km of main roads, of which 58.87% are within 50 km, which is more than half; and 86.04% of China national forest villages are located within 100 km of the main railway, of which 61.84% are within 50 km, which is a relatively high proportion. According to Fig. 3d, most of China national forest villages are near both major highways and railways, indicating that most of China national forest villages

Table 5 Statistics of distances between China national forest villages and roads and railways

Distance (km)	0–50 km	50–100 km	Total
Main road	4466	1862	6328
Main railway	4691	1836	6527

are distributed in places with a dense transportation network. That is to say, China national forest villages are highly accessible. Rural greening and beautification are inseparable from outside support and help, and strong accessibility provides conditions for internal and external communication in the village. In addition, as the saying goes, “If you want to be rich, build roads first.” Rural economic development must rely on convenient transportation facilities. Rural revitalization needs to improve the rural economy and the living standards of rural residents. If they do not keep up with the times, they will eventually lag behind and be eliminated. And transportation has become the conveyor belt for the countryside to keep up with the times.

Economic development level factor

The level of economic development has an important impact on the construction of China national forest villages, and is also an important factor affecting the development of rural tourism. Using ArcGIS 10.3 software, the average of Gross domestic product (GDP) in each region from 2006 to 2020 was divided into five levels according to the natural discontinuous point classification method, and then the permanent residents was superimposed with China national forest villages to obtain the overlay map of GDP (Fig. 3e). From Fig. 3e, it can be found that provinces in the eastern coastal regions, such as Guangdong, Jiangsu, and Zhejiang, rank in the forefront in terms of GDP and the number of villages, while Tibet, Qinghai and Ningxia, which are ranked lower in terms of GDP, also have fewer villages. The results of correlation analysis show that, at the 99% confidence level, the Pearson correlation coefficient between the number of national forest villages and the average GDP from 2006 to 2020 is 0.601, indicating that there is a positive correlation between the distribution of China national forest villages and the level of economic development. It can be seen that the level of economic development is an important factor affecting the distribution of China national forest villages. In areas with a high level of economic development, the funds for the construction of villages are relatively more abundant, and the villagers have a stronger awareness of rural protection. At the same time, the rural tourism market resources in the developed areas are sufficient, and the conditions for the development of China national forest villages are relatively more mature.

Population size factor

The agglomeration of population promotes the formation of rural settlements, and the population size will have a profound impact on rural development. Using ArcGIS 10.3 software, the average of permanent residents in each region from 2006 to 2020 was divided into five levels according to the natural discontinuous point classification method, and then the permanent residents were superimposed with China national forest villages to obtain the overlay map of permanent residents (Fig. 3f). Figure 3f shows that China national forest villages are densely distributed in areas with a large permanent population, such as the central and eastern regions of China. However, areas with a small permanent population, such as the western region, have fewer villages. In general, the distribution of China national forest villages roughly conforms to the Hu Line. The results of correlation analysis show that, at the 99% confidence level, the Pearson correlation coefficient between the number of China national forest villages and the average permanent residents from 2006 to 2020 is 0.820, indicating that there is a significant positive correlation between the distribution of China national forest villages and permanent residents. The larger the population size, the larger the tourism and service market capacity, and the easier it is to promote the development of China national forest villages, thereby affecting the distribution of China national forest villages.

Conclusion and suggestion

Firstly, the nearest neighbor index is used to judge the overall distribution types of China national forest villages, and the Tyson polygon is used to verify it. Secondly, the distribution of each province is refined, and the cold and hot spot analysis method is adopted. Finally, it is refined to specific dense areas and analyzed by the kernel density index. In addition, buffer analysis and overlay analysis are used to further analyze the influencing factors forming this distribution pattern. The results are as follows:

1. According to the nearest neighbor index $R=0.46 < 1$, the spatial distribution type of China national forest villages is preliminarily determined to be condensed. The result is verified by calculating the coefficient of variation of the area of Tyson polygon, $CV=716.12\%$, which is much larger than 64%. The distribution type of China national forest villages is comprehensively recognized as condensed distribution.
2. According to the analysis of cold and hot spots, the distribution of China national forest villages shows the characteristics of “hot in the south and cold in the north.” The hot spots include nine provinces, such as Sichuan and Hubei, accounting for 19.56% of the total area of China. The sub-hot spots include eight provinces (cities), including Jiangsu and Anhui, accounting for 15.43%. The sub-cold spots include eight provinces (cities), including Heilongjiang, Jilin and Liaoning, accounting for 33.83%. Xinjiang, Tibet, Ningxia, and other six provinces (cities) belong to cold spots, accounting for 31.18%. The number of hot spots is more than that of cold spots, but the cold spots account for more than half of the area.
3. According to kernel density analysis, it is found that high-density areas are significantly related to vegetation coverage and the distribution of urban agglomerations. On the one hand, most high-density areas are located within the forest vegetation coverage. On the other hand, the first batch formed high-density areas, such as the Yangtze River Delta, Central Plains and Bohai Rim, and the second batch formed high-density areas, such as the Yangtze River Delta, Central Plains and Beijing–Tianjin–Hebei.
4. Elevation, slope aspect, river, forest resources endowment, traffic, economic development level, and population size were selected as influencing factors to explore their correlation with the spatial distribution of China national forest villages. The study found that elevation, rivers, forest resources endowment, traffic, economic development level, and population size are all significantly correlated with the spatial distribution of China national forest villages. However, due to the specific analysis of the aspect to be combined with many complex factors such as elevation and region, the correlation is weak. In general, the spatial distribution of China national forest villages is characterized by low altitude, sunny distribution, proximity to water sources, rich in forest resources, dense transportation networks, developed economy, and dense population.

Based on the research results obtained, the following policy implications are put forward for the construction and evaluation of China national forest villages. First, from the aspect of the evaluation index, the distribution of China national forest villages shows obvious agglomeration characteristics, which indicates that the current evaluation index has obvious bias. Different regions have different innate advantages and acquired construction. It is suggested that in the future, the evaluation standard of China national forest villages should be adjusted to local conditions and gradually develop to a balanced trend. Second, from the aspect of basin water resources, the distribution of China national forest villages shows obvious “near water” characteristics, and water sources have an important influence on their distribution. In China, water resources are abundant in the south and scarce in the north. Water resources in the south account for more than 80% of the country’s total, while water resources in the north account for less than 20%. Methods such as south-to-north water diversion, artificial rivers and reservoir construction are helpful to solve the problem of uneven water resources and to promote the balanced distribution of China national forest villages. Third, from the aspect of traffic facilities, the accessibility of rural areas is directly determined by the degree of transportation convenience, which also has a greater impact on the level of local economic development, and thus plays an important role in the development and continuation of rural areas. For areas with remote locations and inconvenient transportation, it is recommended that the state and government strengthen the construction and optimization of transportation facilities to provide a foundation for the construction of China national forest villages. Fourth, from the aspect of regional cooperation, the government should vigorously strengthen regional cooperation and rely on the formed spatial pattern of China national forest villages agglomeration to establish internal connections for common development. The eastern region, with its large number of villages and better development, will drive the underdeveloped western region. At the same time, exchanges between urban and rural areas should be strengthened to promote urban–rural integration. The huge radiation effect of big cities is used to drive rural development and inject a lasting impetus into the construction of

China national forest villages. Of course, there are still some shortcomings in this research. The spatial distribution pattern of China national forest villages is the result of many factors. The influencing factors listed in this article are not comprehensive enough. In the future, extended research can be carried out on the basis of this article. The selection of China national forest villages is still in progress, and the list is constantly updated. Subsequent analysis of temporal and spatial evolution can be done, and more and more in-depth impact factors can be explored to provide theoretical references for selection indicators of China national forest villages and rural beautification, construction and development.

Acknowledgements We sincerely wish to give acknowledgement to the reviewers who provided editorial suggestions and comments.

Funding This work was supported by the Science and Technology Research Program of Chongqing Municipal Education Commission (Grant No.KJQN201901129), Humanities and Social Sciences Research Program of Chongqing Municipal Education Commission (Grant No.19SKGH132), Chongqing Social Science Planning Project (Grant No.2019YBGL075), Scientific Research Foundation of Chongqing University of Technology 2019, and Humanities and Social Science Research Project of The Ministry of Education of China (Grant No.20XJCZH001).

Data availability The data in this article come from the website of National Forestry and Grassland Administration of China (<http://www.forestry.gov.cn/>).

Declarations

Conflict of Interest The authors declare no competing interests.

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