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Research article

Spatial-temporal characteristics analysis and ecological environment quality evaluation of forest health care bases in Yunnan, Guizhou and Sichuan provinces

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ABSTRACT

As the forest health care in China is still in the early stage of development, the construction standards of forest health care base are not unified yet, resulting in large differences in the evaluation criterion for the ecological environment of forest health care bases. So, it is urgent to develop a new forest health care ecological environment quality assessment method. Yunnan, Guizhou and Sichuan provinces of China were selected as the study area, the previous 6 batches of 165 national forest health care pilot construction bases were selected as the main data source. This study explored the spatial and temporal distribution characteristics of forest health care bases in the study area using standard deviation ellipses, kernel density estimation method and cold and hot spot analysis. Furthermore, this study evaluated the ecological environment quality of the forest health care bases with a new ecological environment quality evaluation index model, which assembled Fraction Vegetation Coverage (FVC), Wetness (WET), Evapotranspiration (ET), Land Surface Temperature (LST) and Normalized Difference Bare Soil Index (NDBSI). The results are as follows: (1) the forest health bases in the study area are mainly located by the east of the Hu Line with a northeast-southwest distribution direction characteristics, and gradually expanded into a shape of "high in the east and low in the west, multi-point development". (2) the area with ecological environment quality in excellent, good and medium grade accounts for about 87.73 % in the study area, indicating that most of the study area is suitable for the construction of forest health care base. These results can provide a practical guidance for the further rational layout and balanced development of forest health care bases in the study area.

1. Introduction

Forest health care is based on the forest ecological environment, organically combining high-quality forest resources with medical and health care, elderly care services, traditional Chinese medicine industries, etc., to carry out a series of new industries beneficial to human physical and mental health, such as forest rehabilitation, recuperation, health preservation, and leisure [1]. Forest health care can reduce blood pressure, increase parasympathetic nervous system activity, reduce sympathetic nervous system activity, prevent and treat depression, and improve human sleep [2–11]. At the same time, forest therapy and green exercise can also improve people's creativity, reduce work pressure, cause physiological relaxation, improve human immune function, and reduce the body's production

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of stress hormones [3,7,9,12,13]. Moreover, studies have found that the phytocides volatile by plants in forests have good medical effects, which can kill bacteria and fungi, regulate nerve balance, reduce human pain, improve human anti-cancer function, as well as cough and expectorant, relieve asthma, etc. [14,15].

Yunnan, Guizhou and Sichuan provinces, located in the southwestern China, have good forest resources, and the suitable climate and environment are very suitable for the development of forest health care bases. However, the construction of forest health care bases in this region is still in the early stage, the construction standards of forest health care bases don't coincide, and the quality evaluation of forest health care bases which derived mainly by expert evaluation method is adulterated with many subjective factors such as the experience and fondness of different experts, resulting in large differences in the quality of the ecological environment of forest health care bases, which has brought negative effects to the development of forest health care bases. As the suitability of forest health care is mainly related to the ecological environment quality of forest health care base [16–18], it is necessary to further develop a new evaluation method of forest health care base from other perspectives.

Due to the development of remote sensing technology, evaluation method of ecological environment quality has changed from the field acquisition of multi-index evaluation to the evaluation based on remote sensing technology, rapid and large-scale ecological environment monitoring has become possible. The remote sensing ecological evaluation index (RSEI), which has been employed in most ecological environment evaluation, can be improved according to different study areas [17,19–21]. However, most of the remote sensing ecological indices are analyzed based on the results of the first principal component, which is easy to cause information loss, are not especially adapted for ecological environment quality assessment [22]. At the same time, evapotranspiration can reflect the transpiration of vegetation and soil evaporation in the area to a certain extent, which is closely related to the development of forest health care bases [23]. Therefore, a new evaluation method for ecological environment of forest health care base is required.

Thus, taking the Yunnan, Guizhou and Sichuan provinces as the study area, the 165 national forest health pilot construction bases which released in the first 6 batches as the main data, this paper firstly analyzes the spatial and temporal distribution of the forest health care bases by GIS spatial analysis methods to get the Spatial-temporal distribution characteristics of forest health care bases in the study area, and then uses the fraction vegetation coverage (FVC), the Wetness (WET), the evapotranspiration (ET), the land surface temperature (LST) and the normalized difference bare soil index (NDBSI) indicators to form a new ecological environment evaluation index model to evaluate the ecological environment quality of forest health care bases in the study area. The results are conducive to a more reasonable allocation of forest health care resources, and provide a certain basis and reference for the site selection layout and construction planning of forest health care bases in the study area.

2. Methods

2.1. Study area

Yunnan, Guizhou and Sichuan provinces are located between 97°21′∼109°35′ east longitude and 21°8′∼34°19′ north latitude, with a total area of 1.0552 million square kilometers, which accounts for 10.59 % of the total land area. By the end of 2019, the three provinces had 46 prefecture-level administrative districts with a total of 400 county-level administrative divisions under their jurisdiction. The overview map of the study area is shown in Fig. 1, and the grid annotation in the map indicates the coordinates in meters in a local projected coordinate system.

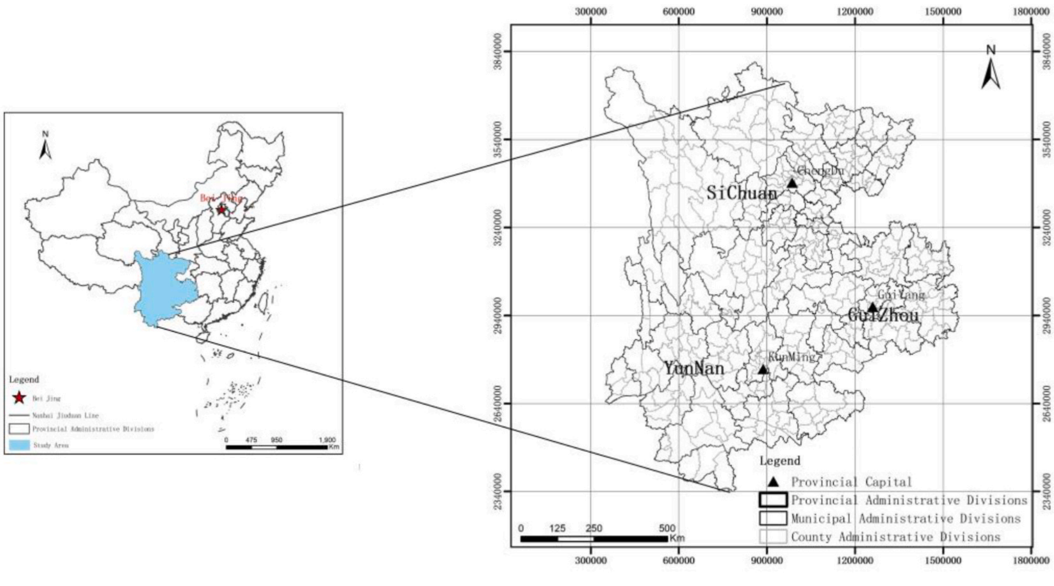


Fig. 1. Administrative division map of Yunnan, Guizhou and Sichuan provinces.

The study area is rich in forest resources, with a wide variety of plant species and developed eco-tourism. Yunnan got a forest coverage rate of 62.4 %, a forest volume of 2.02 billion cubic meters, a grassland comprehensive vegetation coverage rate of 87.9 %, and a total eco-tourism and forest health care industry output value of 15 billion yuan in 2019. Guizhou is one of the four major Chinese herbal medicine producing areas in China, with a forest coverage rate of 60 %, a forest volume of 570 million cubic meters, and a total forestry output value of 337.8 billion yuan in 2020. And Sichuan had a forest coverage rate of 39.63 %, a forest stock of 1.897 billion cubic meters, a grassland comprehensive vegetation coverage rate of 85.6 %, and a direct income from ecotourism of 115 billion yuan in 2019.

2.2. Data

The data used in this paper mainly includes forest health bases data and remote sensing image data, and the data types include text and raster. Since the release time of the sixth batch of forest health care bases was April 2020, the ecological index data in 2019 was selected in this paper.

According to the list of six batches of forest health care pilot bases released by the China Forestry Industry Federation, there are 165 forest health care pilot bases in Yunnan, Guizhou and Sichuan provinces. As the base area is too small to be seen as a polygon in the whole study area, so each base is regarded as point data in this paper, and the bases are transformed into a geographical entity with spatial coordinates through geocoding.

The remote sensing image data comes from the Google Earth Engine (GEE) remote sensing cloud computing platform, and the MCD43A4.006 MODIS lowest bidirectional reflection distribution function (BRDF) was used to adjust the reflectance data of these data. In order to avoid the influence of clouds, ice, and snow, the median synthesis method was adopted to reconstruct the target year image, then vegetation cover, humidity, and dryness data for target year were obtained in the study area.

As a matter of fact, the ecosystem absorbs heat in the surrounding air through vegetation transpiration and soil evaporation, increases the content of air moisture, and achieves the effect of adjusting regional temperature and humidity [23]. Thus, besides the original greenness, humidity, heat and dryness indexes of the ecological remote sensing index RSEI, Evapotranspiration (ET) is introduced to construct the ecological environment evaluation index of the forest health base, and the annual evaporation data of the study area were selected from the MOD16A2.006 evapotranspiration/latent heat flux product data on the GEE platform in the study area.

2.3. Spatial distribution study methods

In this paper, standard deviation ellipses were used to analyze the overall spatial distribution of forest health care bases in the study area, kernel density estimation method was used to explore the spatial aggregation and distribution of forest health care bases in the study area, and the spatial distribution and aggregation degree of forest health care bases in the study area were analyzed by cold and hot spot analysis.

2.4. Principal component analysis

Principal Component Analysis (PCA) method was employed to aid in constructing the remote sensing ecological environment quality evaluation model to avoid the influence of human subjective consciousness on the determination of weights in this paper. PCA is a method to recombine the original multiple variables with strong correlation, then generate a few variables that are not related to each other while extracting as much of the original data information as possible. PCA generally selects the first principal component to construct a new composite indicator. When the first principal component is not enough to represent the information of all the original indicators, the remaining principal components are taken into account. There are generally two methods for determining the number of principal components, the first is by the principle that whether the eigenvalue is greater than 1, and the second by the principle that whether the cumulative contribution rate is greater than 85 %. In this paper, the second method is selected to determine the number of principal components, and then the weight of rating factors.

2.5. Construction of ecological environment evaluation index model

Due to the certain differences in forest resources in different regions, the distribution of forest health bases alone is not enough to explain whether the development of forest health bases in this area is reasonable, and the quality of the natural ecological environment is also very important. As forest health care is closely related to the quality of the ecological environment, and from the perspective of ecological environment, it can provide a basis for the construction and development of forest health care base from a macro perspective. In order to analyze the ecological environment quality of the forest health care base in the study area from a macro perspective, based on the Remote Sensing Ecological Index (RSEI), FVC(Fraction Vegetation Coverage), WET (Wetness), ET (Evapotranspiration), LST (Land Surface Temperature) and NDBSI(Normalized Difference Bare Soil Index), which are the five representative factors related to the ecological environment quality of the forest health care bases, are selected to construct the ecological environment quality evaluation index model suitable for the forest health care base by the aid of PCA.

To avoid the influence of large-scale water areas on the humidity index and then affect the principal component analysis results, the water body information in the remote sensed data was removed based on the improved normalized differential water body index (MNDWI) firstly. Next as the dimensions and value ranges of FVC, WET, ET, LST and NDBSI indicators derived from the remoted sensed data were different, these data should be standardized to [0–1] respectively by Equation (1):

$$Y = \frac{X - X_{min}}{X_{max} - X_{min}} \tag{1}$$

where X represents the initial value of a factor for some point, Y is the normalized value of the factor for the same point, X_{min} represents the minimum value of all values of the factor, and X_{max} denotes the maximum value of all values of the factor.

As the actual boundary of each forest health care base is not available, according to the "Quality Assessment of Forest Health Care Base" (LY/T2934-2018), which specifies that the total forest area of the base and its adjacent area is not less than 1000 hm^2, therefore, a buffer zone for each forest health care base with an area of 1000 hm^2, established around the coordinates of the forest health care base, acts as the range of the forest health care base. Thus, the average values of the five factors of each health care base can be obtained by the zonal statistical method.

Then, the principal component analysis was performed on these average values, and the former principal components with the cumulative contribution rate greater than 85 % were synthesized to obtain the weight value for each factor by Equation (2):

$$S = \frac{\sum_{i=1}^{n} \omega_i \times PC_i}{\sum_{i=1}^{n} \omega_i} \tag{2}$$

where ω_i represents the variance contribution rate value of the factor for the ith principal component, n represents the number of

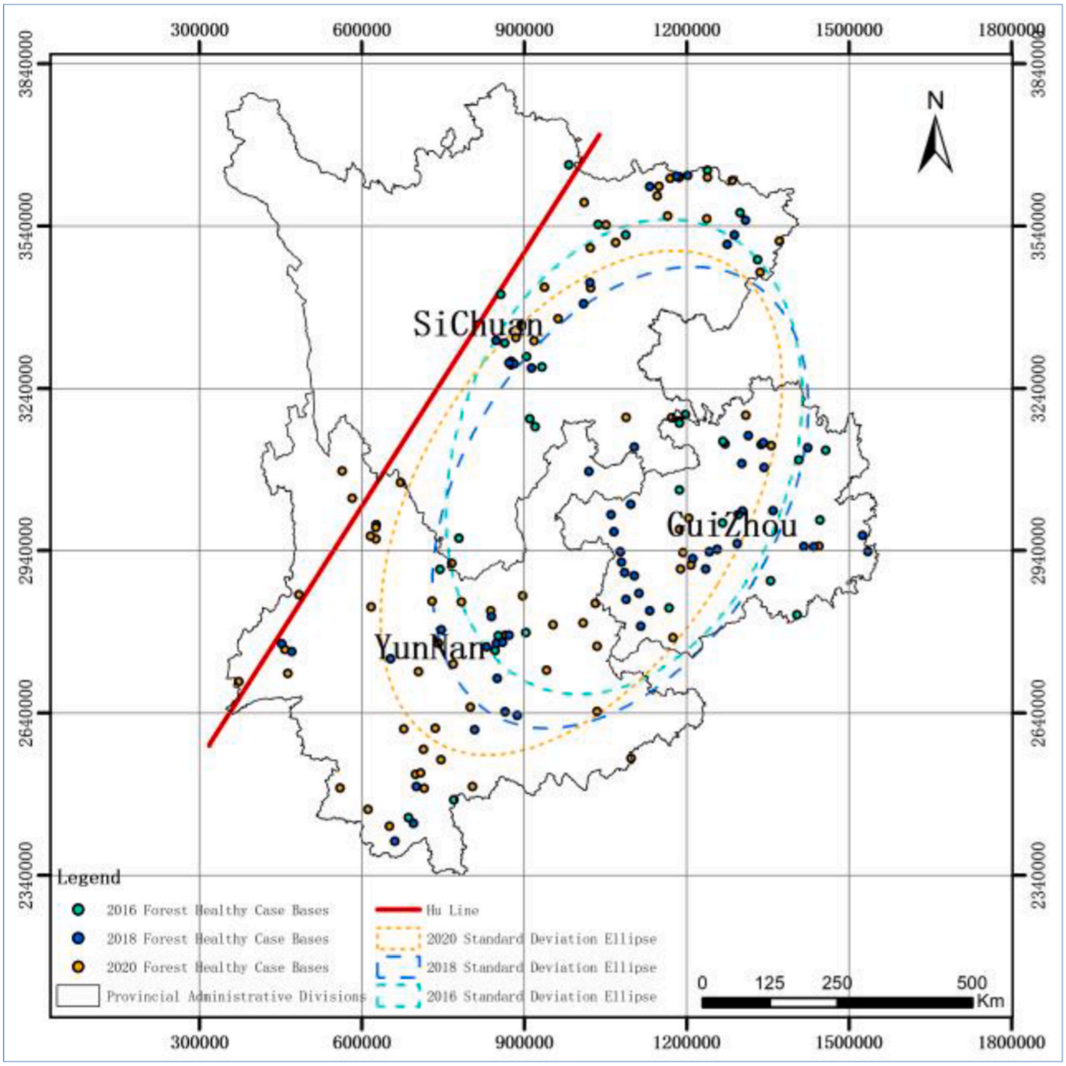


Fig. 2. Ellipse analysis of standard deviation of forest health care bases in Yunnan, Guizhou and Sichuan provinces.

principal components selected, and pc_i represents the contribution value of the factor for the ith principal component.

Then, the ecological environment evaluation index for some point can be calculated by Equation (3):

$$EEI = \sum_{j=1}^{m} S_j \times F_j \quad (3)$$

Where S_j is the weight value for a factor, F_j is the value of the factor for the point, and m is the number of all factors.

Finally, the obtained ecological environment evaluation index is standardized to [0–1], and the larger the index, the better the ecological environment quality of the area.

3. Results

3.1. Spatial-temporal distribution characteristics of forest health care bases in study area

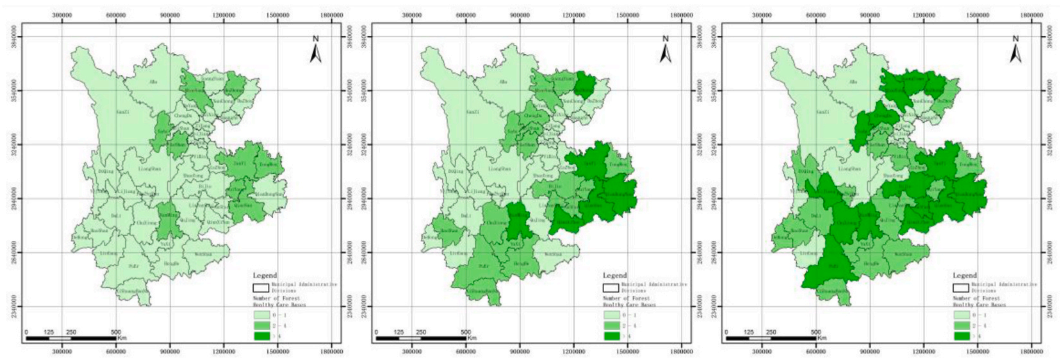
1) Overall spatial distribution

The spatial distribution of the 165 national forest health care pilot bases and the standard deviation ellipses for 2016, 2018 and 2020 are shown in Fig. 2. From the figure, it can be seen that the standard deviation ellipses are all located by east of the Hu Line with northeast-southwest characteristics in distribution direction, and the ellipses distribution range gradually expands with time. The figure also shows that the spatial distribution of forest health care bases in Yunnan, Guizhou and Sichuan provinces is uneven, mainly due to the high altitude, few forest resources, bad climatic environment, mall population and low economic development by west of Hu Line.

The number of forest health care bases by the years of 2016,2018 and 2020 in the three provinces are shown in Fig. 3. The number between 0 and 1 is low, indicating that the development of forest health care bases in the city is relatively lacking; the number between 2 and 4 is medium, indicating that the development of forest health care bases is moderate; and the number greater than 4 is high, indicating that the development of forest health care bases in the city is good. From Fig. 3a–b and c, it can be seen that from 2016 to 2020, the number of forest health care bases has been increasing. From Fig. 3c, it can be seen that by 2020, each city and prefecture in Guizhou province has a good development of forest health care bases, Lincang city is the only city in Yunnan province has no forest health care base, while Deyang and other 9 prefecture-level units in Sichuan province have no forest health care base, indicating that Sichuan province forest health care bases distribution is the most uneven at prefecture-level.

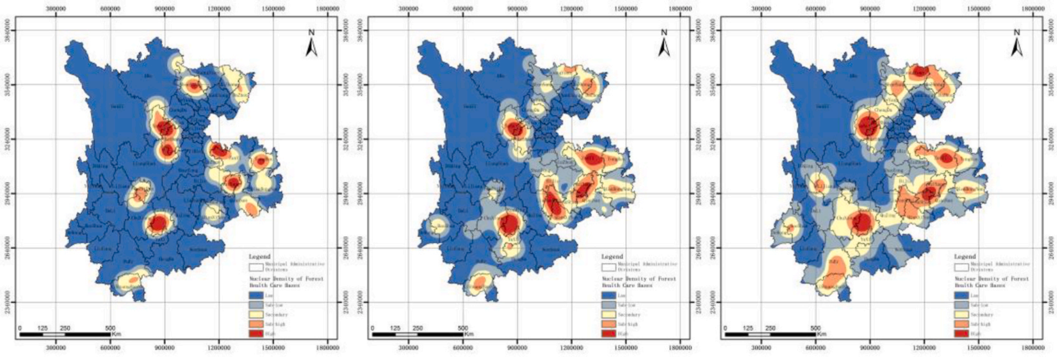
2) Spatial-temporal distribution characteristics

The aggregation distributions of forest health care bases by the years of 2016,2018 and 2020 in the study area analyzed by nuclear density method are shown in Fig. 4. From the figure, it can be seen that the area with high-value areas in nuclear density are mainly concentrated in the south-central, north-central and eastern areas of the study area, showing the distribution characteristics of "high in the east and low in the west, multi-point development", with the development of time, the high-value area gradually spreads, and the low-value area decreases, by 2020 (Fig. 4c), the low-value area is mainly concentrated in the middle of the study area, the northwest, southwest and southeast of Sichuan province. Specifically, in 2016 (Fig. 4a), the areas with high nuclear density were mainly concentrated in Kunming of Yunnan province, Guiyang, Zunyi, Tongren of Guizhou province, Mianyang, Ya'an, Meishan and Leshan of Sichuan province, scattered in dots, with limited outward radiation areas and more low-density areas. In 2018 (Fig. 4b), compared with 2016, the high-value areas further spread around, mainly forming the distribution characteristics of "four points and one side"; "four points" mainly refers to Yameile (Ya'an, Meishan, Leshan) of Sichuan province, Kunming of Yunnan province, Bazhong of Sichuan province, Xishuangbanna of Yunnan province and other places, and "one side" refers to a large area of high-density areas formed by Liupanshui, Guiyang and Zunyi of Guizhou province, indicating that the overall development of Guizhou province is better;



(a) 2016 (b) 2018 (c) 2020

Fig. 3. Distribution of the number of forest health care bases in different cities.



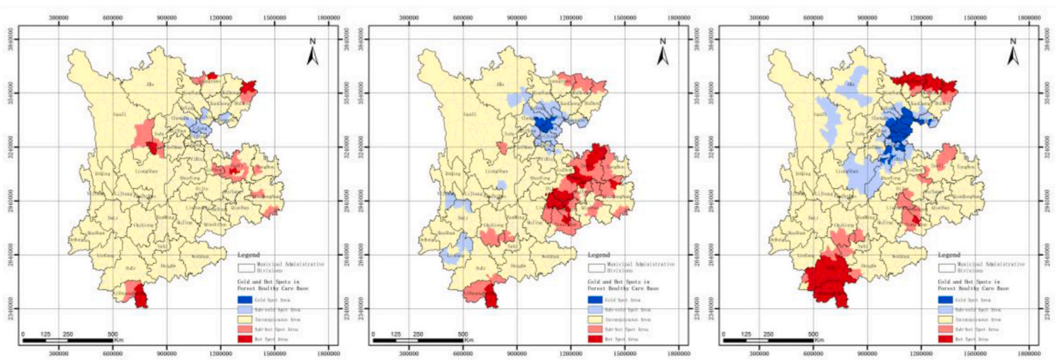
(a) 2016 (b) 2018 (c) 2020

Fig. 4. Nuclear density diagram of forest health care bases.

Yunnan and Sichuan are less developed and show obvious high-value and low-value areas. In 2020 (Fig. 4c), the high-density area of the three provinces will be further expanded, with the high-density areas of Guizhou and Yunnan provinces mainly in Kunming of Yunnan province, Guiyang and Zunyi of Guizhou province, and connected; Sichuan province presents an inverted “L" shape, forming a high-density area with Yameile and Guangyuan and radiating to both sides, and the low-density area is mainly concentrated in Ganzi, Aba and Liangshan prefectures and eastern prefecture-level units of Sichuan province.

Cold and hot spot analysis method was employed to identify the hot spots and cold spots in different areas of forest health care bases to further analyze the spatial distribution and aggregation degree of forest health care bases in this paper. Fig. 5 shows the results of hot and cold spot analysis based on the data of forest health care bases in the three provinces county-level administrative divisions in 2016, 2018 and 2020. It can be seen from the figure that in 2016 (Fig. 5a), there were 5 county-level units in the hot spot area, and 17 county-level units in the sub-hot spot area, mainly distributed in the southern, eastern and north-central parts of the study area; while the sub-cold spot area had a total of 10 county-level units, mainly distributed in the southeast of Sichuan province in the study area; the hot spot area was more than the cold spot area, but on the whole, there were fewer of both, and the distribution of the hot spot area was more scattered; the cold spot area was more concentrated, with Ziyang city as the leader spreading to the surroundings. In 2018 (Fig. 5b), compared with 2016, the hot spots in the south and east of the study area were further expanded, and the hot spots in central Yunnan province were added, and the hot spots near Ya’an of Sichuan province became smaller; the cold spot area was further expanded on the basis of 2016, covering 13 prefecture-level units in Sichuan province, and blocky cold spots also appeared in the western part of Yunnan province, indicating that the forest health care base in Sichuan and Yunnan was poorly developed. In 2020 ((Fig. 5c)), the hot spots in Guizhou province decreased and separated into three areas; except for the hot spot area in Ya’an of Sichuan province, the hot spot area in the other two places further spread outward to form a large hot spot; the cold spot area in the west of Yunnan province disappeared, and the southeastern Sichuan province and the Ganzi, Aba and Liangshan prefectures became the main cold spot gathering area. On the whole, the cold spot area showed a gradual expansion trend, mainly distributed in Sichuan, indicating that the development of forest health care bases in Sichuan province was the most unbalanced, and relevant counties and cities should pay attention to the development of forest health care bases and further strengthen policy guidance; hot spots showed an expansion trend, and developed from block to surface, indicating that hot spots drove the development of surrounding counties to a certain extent.

From the spatial and temporal distribution of forest health care bases in the three provinces, it can be seen that there is an uneven



(a) 2016 (b) 2018 (c) 2020

Fig. 5. Distribution of cold and hot spots in forest health care bases.

spatial distribution and concentrated distribution in the development of forest health care bases.

3.2. Ecological environment evaluation of forest health care bases in Yunnan, Guizhou and Sichuan provinces

In this paper, the values of each index of the 165 forest health care bases were used as samples, and the weight of each evaluation index in the construction of forest health ecological environment quality index was determined by principal component analysis. The results of principal component analysis are shown in Table 1, and the cumulative contribution rate of the first two principal components reaches 89.35 %, which is greater than 85 %, so the first two principal components are selected to construct the ecological environment quality evaluation index. The surface dryness's attributions to the first two principal components were both negative, and the contributions of the vegetation coverage and surface evapotranspiration were both positive, indicating that the influence of these three indices on the ecological environment quality of the forest health base is relatively stable, while the contributions of the surface humidity and the surface temperature to the first principal component were jarred with the contributions to the second principal component, indicating that the influence of these two on the ecological environment quality of the forest health care base was unstable.

Then, the comprehensive coefficients for the five factors (FVC, WET, ET, NDBSI, LST) were obtained as 0.437, 0.343, 0.447, −0.453 and −0.117 respectively. The negative coefficients for NDBSI and LST indicate that the surface dryness and surface temperature are inversely proportional to the quality of forest health ecological environment, the larger the value, the worse the ecological environment; while the positive coefficients for WET and ET indicate that the Surface humidity and surface evapotranspiration are directly proportional to the quality of the ecological environment, and the larger the value, the better the ecological environment quality of the forest health care base, which is consistent with the actual situation.

The correlation between the ecological environment quality evaluation index of the forest health bases and the factors is shown in Table 2, which is used to analyze whether the ecological environment quality index of the newly constructed forest health base is more suitable for evaluating the ecological environment quality in the base than a single factor. In terms of individual factors, the highest average correlation was FVC and NDBSI, reaching 0.754, while the average correlation between the newly constructed ecological index and each indicator reached 0.807, higher than the maximum value of individual indicators. Contrasting to a single factor, the newly constructed index can better represent the ecological environment quality of the region; at the same time, FVC, WET, ET are positively correlated with the evaluation index, and NDBSI and LST are negatively correlated with the evaluation index, further illustrating the relationship between each factor and the ecological environment evaluation index. However, the correlation between LST and evaluation index is relatively low, which indicates that the influence of LST on ecological environment quality is weak to a certain extent.

The constructed ecological environment quality evaluation index was then graded into five grades: poor (0.0–0.2), sub-poor (0.2–0.4), medium (0.4–0.6), good (0.6–0.8), and excellent (0.8–1.0) at intervals of 0.2 to further analyze the distribution of ecological environment quality of forest health care bases in the study area. The grading results of the ecological environment quality evaluation index in the statistical study area are shown in Table 3. From the table, it can be seen that the area with good ecological environment quality in the study area is the most, accounting for nearly half of the research area, followed by the area with medium ecological quality, accounting for one-third of the entire research area, and the area with excellent ecological quality accounts for 7.4 %, and the cumulative proportion of the three reaches 87.73 %, indicating that most of the research area is more suitable for the construction of forest health care bases; while the proportion of poor ecological environment quality is the smallest, only 1.25 %, and the proportion of sub-poor is also smaller, 11.02 %, indicating that there are few areas in the study area that are not suitable for building forest health care bases.

Then, the grading map of the ecological environment quality evaluation index of the forest health care base in the study area is shown in Fig. 6, and the areas with poor ecological environment quality are mainly distributed in the south-center, northwest and northeast areas of the study area, usually in contiguous areas, and a small number are scattered in various cities, indicating that in addition to the impact of urban construction area, the poor ecological environment quality in other areas has a certain agglomeration. According to the index results of each forest health care base, 97 % of the forest health care base ecological environment quality is at the medium level or above, and 73.3 % of the forest health care base ecological environment quality is at a good level or above, indicating that areas with good ecological environment quality are more suitable for the development of forest health care base.

From the analysis at province-scale, the distribution of high and low values in Sichuan province is obvious, and the low value areas are mainly distributed in the Chengdu Plain, the northwest part and the south part of the province. The poor ecological environment quality in the Ganzi, Aba and Liangshan prefectures was largely due to the low vegetation coverage, large terrain undulations, poor climatic conditions, sparse population in the area; the poor ecological environment quality of Panzhihua city was mainly caused by the

Table 1
Principal component analysis results.

	PC1	PC2	PC3	PC4
FVC	0.949	0.135	−0.192	−0.179
WET	0.834	−0.093	0.54	0.016
ET	0.927	0.242	−0.201	0.196
NDBSI	−0.954	−0.209	−0.014	0.038
LST	−0.612	0.775	0.157	−0.018
Eigenvalues	3.738	0.729	0.393	0.073
Cumulative contribution (%)	74.763	89.347	97.212	98.212

Table 2
Statistical table of correlation between ecological evaluation index and indicators.

Indicator	FVC	WET	LST	NDBSI	ET	S
FVC	–	0.680	−0.500	−0.912	0.922	0.950
WET	0.680	–	−0.496	−0.770	0.649	0.716
LST	−0.500	−0.496	–	0.424	−0.413	−0.461
NDBSI	−0.912	−0.770	0.424	–	−0.911	−0.944
ET	0.922	0.649	−0.413	−0.911	–	0.964
Average correlation	0.754	0.649	0.458	0.754	0.724	0.807

Table 3
Statistical table of ecological environment evaluation index level and area proportion of forest health care bases in study area.

Ecological level	Area/km^2	Percentage%
Poor	12715	1.25
Sub-poor	112133	11.02
Medium	341031	33.52
Good	476132	46.81
Excellent	75242	7.40

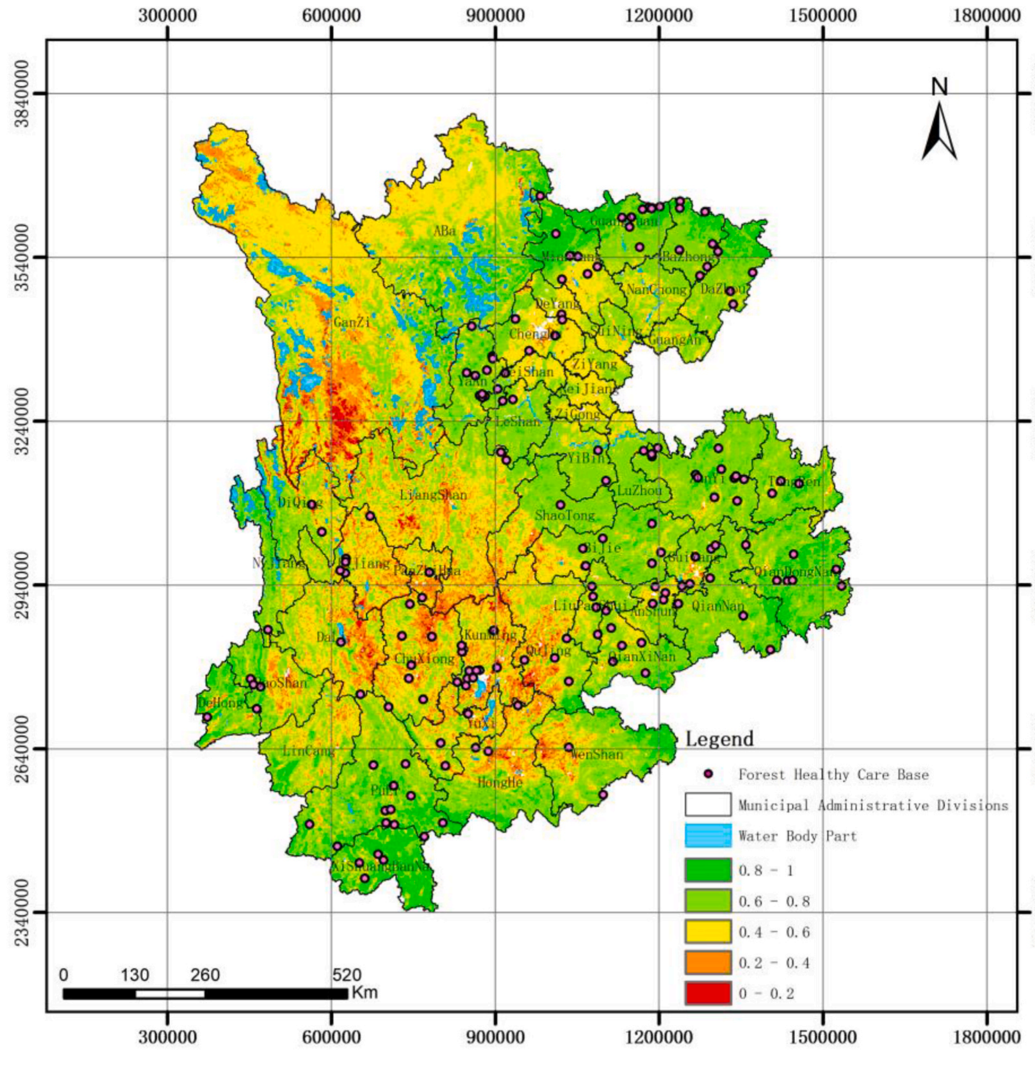


Fig. 6. Grading chart of ecological environment evaluation index of health care bases in Yunnan, Guizhou and Sichuan provinces.

mining activity, the serious soil erosion, and the typical hot and dry river valley environment; while the poor ecological environment quality in Chengdu plain was resulted from the large population density and the developed urban construction. Moreover, there was no forest health base distributed in the hilly area of central Sichuan province, this may be caused by the serious soil erosion, the low vegetation coverage and the lack of implementation of relevant policies. However, according to the results of the ecological environment assessment, the ecological environment quality in most of this area is medium or at better level, indicating that it can find the potential forest health care bases in this area. Therefore, some forest health care bases with local characteristics can constructed on the base of existing state-owned forest farms, forest parks and other places, where has a relatively high ecological environment quality.

Most prefecture-level units have a poor ecological environment in Yunnan province, excepting Pu'er city, Nujiang, Dehong and Xishuangbanna. The overall trend of decreasing from west to east and from south to north is mainly caused by the area belongs to the dry and hot river valley area, and the southeast is affected by karst landforms, resulting in poor water and soil conservation capacity, and then leading a poor ecological environment quality. However, only Lincang city in Yunnan province does not have a forest health care base, but in terms of its ecological index distribution, most of its areas are in the level of good ecological environment, and Lincang city has a number of nature reserves and national forest scenic spots, which has a good foundation for building a forest health care base.

The overall ecological environment quality of Guizhou province is good, and there are only some areas with poor ecological environment, and its distribution is mainly concentrated in the western prefecture-level units such as Bijie, Anshun, Liupanshui and Qianxinan, mainly because the area is rich in mineral resources and affected by the resource development process, resulting in the poor ecological environment and serious soil erosion; at the same time, the typical karst landforms in the western region have the problem of fragile ecological environment. In addition, Guiyang also has areas with poor ecological environment, this may be caused by the economic development center of Guizhou province and the proliferation of illegal mining in the area leading a serious damage to the ecological environment.

From the analysis results of the ecological environment quality of forest health care bases, Guizhou province is suitable for the development of forest health care bases as a whole, and the existing forest health care bases are distributed in various prefecture-level units. However, there is also an uneven distribution phenomenon, the prefecture-level unit with the largest number of bases is almost four times the number of prefecture-level unit with the least, and more than half of the county-level units has ecological environment quality above the medium level but without forest health care base. Thus, the construction of forest health care bases should be further accelerated with the help of the infrastructure of relevant scenic spots to make a better use of the better ecological environment in these areas. On the other hand, the area with poor ecological environment quality should adjust the industrial structure scientifically and rationally to rebuild a good ecological environment, and then realize the construction and development of forest health care bases.

4. Conclusion and discussion

By analyzing the spatial and temporal distribution of forest health care bases in Yunnan, Guizhou and Sichuan provinces and the quality evaluation of forest health care ecological environment, the main research conclusions of the paper are as follows:

(1) Forest health care bases in study area are basically located east of Hu line, and their distribution direction also shows northeast-southwest characteristics, with the development of time, its distribution range gradually expands; under the prefecture-level scale, the prefecture-level units with better development of forest health care bases increase year by year, while the prefecture-level units with poor development are mainly concentrated in Sichuan province. From the perspective of spatio-temporal distribution characteristics, the high-value areas of the nuclear density of the forest health care base are mainly concentrated in the south-central, north-central and eastern areas of the research area, showing the distribution characteristics of "high in the east and low in the west, multi-point development", with the development of time, the high-value area gradually spreads, and the low-value area decreases, by 2020, the low-value area is mainly concentrated in the middle of the study area, the northwest, southwest and southeast of Sichuan province. From the distribution of cold and hot spots, the cold spot area of forest health care base shows a gradual expansion trend, mainly distributed in Sichuan province, indicating that the development of forest health care base in Sichuan province is the most unbalanced, and relevant counties and cities should pay attention to the development of forest health care base and further strengthen policy guidance; hot spots show an expansion trend, and develop from block to surface, indicating that the hot spot area has driven the development of surrounding counties and districts to a certain extent, showing a trend of point and surface.

(2) From the results of the ecological environment quality assessment of the forest health care base, nearly half of the study area has a good ecological environment quality, followed by the area with medium ecological quality, accounting for one-third of the entire research area, the area with excellent ecological quality accounts for 7.40 %, and the cumulative proportion of the three reaches 87.73 %, indicating that most of the areas in the study area are more suitable for the construction of forest health care bases, while the proportion of poor ecological environment quality and poor is small, indicating that there are few areas that are not suitable for the construction of forest health care bases. In terms of spatial distribution, the low-value areas were mainly distributed in the eastern, southern and northwestern areas of Sichuan province, the southeastern part of Yunnan province and the western part of Guizhou province, and the high-value areas showed an "S" shape running through the three provinces.

This paper provides a practical guidance for the further rational layout and balanced development of forest health care bases in the study area, which has certain practical significance. However, due to the large study area and large cloud cover, it is difficult to obtain cloudless data in a short period of time, the image of the study area can only be reconstructed through multiple images in a long series, so that the image cannot reflect the surface situation of the research area well. In future research, other high-resolution cloudless remote sensing images can be reasonably selected to avoid the bias caused by image data to the research.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

CRediT authorship contribution statement

Wei Li: Writing – original draft, Resources, Data curation. **Ji Jian:** Writing – review & editing, Methodology, Conceptualization. **Ke Lu:** Writing – review & editing, Resources, Data curation.

Declaration of competing interest

The authors 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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