Study on Forest Health Assessment of eastern Qilian Mountains in Qinghai Province

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Abstract . A total of 17 indexes including forest structure, productivity, stability and soil quality were established in the eastern Qilian Mountains. The weights of the indexes were determined by side analysis and entropy weight method. The health status of forest resources in eastern Qilian Mountains of Qinghai Province was evaluated by comprehensive weighting method. The results showed that the distribution and health level of forest resources in the eastern Qilian Mountains of Qinghai province were sub-health.

Keyword: Qinghai Province; Eastern Qilian Mountains; Index system; Health evaluation.

1. Introduction

Forest ecosystem is a complex multifunctional ecosystem on earth [1], which can conserve water source, conserve soil and water, provide living materials and places for organisms [2], and maintain the survival and development of human society [3]. In recent years, With the decline of global environmental quality, climate warming and the decline of forest vegetation system function, it is an urgent problem to be solved nowadays to evaluate and predict the health status of forest ecosystem process and service function from the perspectives of forestry, ecology and ecological economics [4][5]. The various ecological service functions of forest ecosystem are declining continuously, so the forest ecosystem health management method which mainly focuses on forest restoration comes into being.

In western countries, the concept of forest health was first put forward in response to problems such as single stand structure of plantation forest, serious damage of forest diseases, insects and rodents, weak ability of control and water and soil conservation [6][7]. In the 1970s, German scholars proposed the concept of forest health, and other European countries also began to observe and evaluate the state of forest health [8][9]. In the 1990s, the United States improved the concept of forest health on the basis of "integrated management of forest pests and diseases[10], and Canada, Australia and other countries also began to pay attention to forest health [11]. China began to study forest health in the 1980s, and began to study the impact of acid rain on single species and stands [12]. Forest health can be divided into broad sense and narrow sense. The narrow sense of forest health emphasizes that the forest itself is free from pests and diseases and fire threats. Forest health in a broad sense means that the ecological resources of regional and forest ecosystem can not only satisfy the stable and healthy development of themselves, but also satisfy the reasonable living needs and production development of human beings [13-15].

Gao Junkai [16] analyzed the concept and attribute characteristics of forest health under modern conditions. He proposed that the connotation of forest health under modern conditions is the relationship between subject and object. He regarded the healthy forest as a structure with its own good existence, self-renewal and ecological service function. Xiao Fengjin et al. [17] established an evaluation index system, including vitality, organizational structure and resilience, to evaluate the national forest health status and analyze the spatial distribution of national forest health based on remote sensing data, national meteorological data, forest statistical data and survey data of national forest sample plots. Wang Xiongbin [18] et al. objectively evaluated the health status of Pinus

oleformis forest in the soil and stony mountains of North China through principal component analysis and cluster analysis. According to the health index of the sample plot, the forest health level was divided into five categories, and it was judged that the health status of the natural forest in the study area was higher than that of the plantation forest. Dong Lingbo et al. [19] analyzed how to convert the research scale of forest health assessment. Taking Pangu forest farm in the Greater Hinggan Mountains as an example, they constructed a single wood scale model and a comprehensive forest scale health model respectively, and found that the comprehensive forest scale health model could meet the requirements of health assessment, and the health assessment results of single tree, stand and regional scale could be effectively converted by statistical methods.

Through the literature on forest health evaluation in China, we know that there is no unified standard on forest health evaluation in China, and the evaluation methods are different in different regions, and the construction of evaluation index system is also different. In the eastern Qilian Mountains, the single function of soil and water conservation is the goal of forest vegetation construction, and the pure forest structure is poor, the growth rate is low, the natural regeneration is lack, and the stability is poor. This study hopes to analyze forest resources and forest-related factors, so as to give a comprehensive interpretation of forest ecosystem health assessment in the eastern Qilian Mountains of Qinghai province.

2. Overview of the study area

Located at 95°~102° E and 37°~39 ° N, the Qilian Mountains have typical continental climate and plateau climate, with a large temperature drop in winter and a large annual temperature difference. The average annual odor in the eastern part of the Qilian Mountains is generally above -3.0℃, and the precipitation shows an east-west decreasing trend. In the eastern region, a precipitation concentration area is formed [20], with annual precipitation of about 150mm. In this area, the elevation difference is large, the topographic conditions are complex, and the water and heat conditions are obviously different, which gradually increases with the degree of drought from east to west. The eastern mountainous area is rich in water resources [21]. The main landform of Qilian Mountain water conservation area is mountainous, with gully and basin. The forest area is 2954.75km2, and the forest coverage rate is 4.63%, which is higher than that of the whole province. For the whole province, it has typical and exemplary significance. See Figure 1.

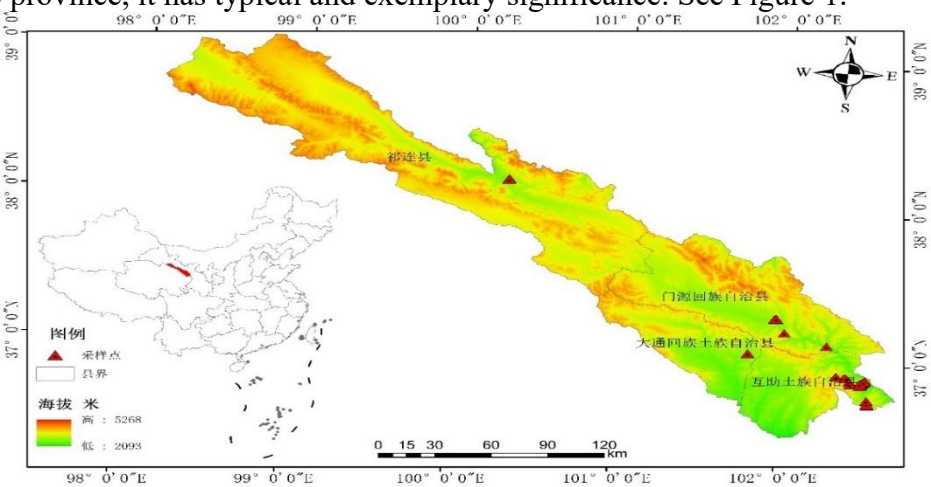

Figure 1 Overview of the study area

3. Construct the index system of forest health assessment

3.1 Index system design

The selection of evaluation indexes is the key to forest ecosystem health evaluation. A scientific, reasonable and highly applicable evaluation index system directly affects the accuracy of evaluation results. The evaluation index system of forest health should be built in accordance with systematic,

rational, simple, feasible and scientific principles based on factors such as the scale and objectives of forest health monitoring [22]. To construct a forest ecosystem health evaluation index conforming to forest resource characteristics and forest situation in the eastern Qilian Mountains of Qinghai province [23]. See (Table 1).

Table 1 Forest health assessment system in the eastern Qilian Mountains

Target layer A	Mesosphere B	Index layer C
Forest health assessment system in eastern Qilian Mountains	Forest structure B1	Stand density C1 Shrub coverage C2 Community structure C3 Canopy density C4 Angular scale C5 The size ratio C6
	Forest community productivity B2	Advantage high C7 The storage is C8 Shrub and grass biomass C9 Natural Renewal C10
	Forest stability B3	Forest fire risk class C11 Infestation degree of disease, insect and mouse C1 Human interference degree C13 Snow pressure C14
	Forest soil quality B4	Humus thickness C15 Soil moisture content C16 Soil organic matter C17

3.2 Determination of index weights

The determination of weight is an important link in forest health evaluation. In this paper, the weight value is multiplied by the standardized value of data to calculate the forest health score, which can be divided into subjective and objective assignment. The commonly used subjective assignment methods include geometric average method, analytic hierarchy process [24], mean value method, etc., which is based on the experience and preference of experts and scholars and has strong personal factors. The commonly used objective assignment methods are coefficient of variation method, entropy method, Gini coefficient weighting method, etc. The weight obtained depends on the information of the data itself. In this paper, the weight obtained by subjective method (analytic hierarchy process) and objective method (entropy method) is combined to obtain the final weight of the evaluation index.

3.2.1 Subjective weighting based on Analytic Hierarchy Process

According to the index system of forest health evaluation in the study area, this study prepared expert questionnaires. A total of 30 questionnaires were distributed to invite forestry related experts and scholars, forest farm staff and forestry related graduate students to score the important values of indicators according to their work and research experience, and then collect them for statistics. The judgment matrix is constructed according to the investigation results, and the indicators of each criterion layer are compared in pairs, as shown in Table 2. Then the consistency test is carried out for the single sort and total sort of hierarchy.

Table 2 Scale table

Index i is compared with index j	**assignment**
Index i is as important as index	1
Index i is slightly more important than index j	3
Index i is more important than index j	5
Index i is more important than index j	7
Index i is extremely important than index j	9
The median value of the judgment	2，4，6，8

3.2.2 Objective weighting based on entropy weight method

The entropy weight method uses the information entropy of each index to determine its weight. The index with low information entropy contains more information, and its weight is correspondingly larger, which mainly includes three parts: index standardization, information entropy calculation and weight calculation.

3.2.3 Comprehensive empowerment

The weights of analytic hierarchy process (AHP) and entropy value method have been obtained. Because the subjective factors of the weights of analytic hierarchy process are large, the construction of the comparative matrix reflects the personal will of the builders. The law of entropy relies entirely on the information contained in the data itself.

Therefore, this paper uses formula (3-3) to calculate the combined weight of the two weights, which not only preserves the subjective will of experts, but also reflects the attributes of the data itself. Therefore, the combined weight will be the final weight of the evaluation index in this paper.see Table 3.

$$W_j = \frac{W_{1j} \times W_{2j}}{\sum_{j=1}^{m} (W_{1j} \times W_{2j})}, \quad (j=1, 2, \ldots, m; 0<a<1) \qquad (3\text{-}3)$$

Where: Wj -- combined weight; W1j -- Analytic hierarchy process to obtain weight; W2j -- entropy method to obtain weight; j - Index number;

Table 3 Calculation results of combination weight

evaluation index	Subjective weight	Entropy has a lot of power	combination weight
Stand density C1	0.029	0.072	0.051
Shrub coverage C2	0.008	0.020	0.014
Community structure C3	0.010	0.016	0.013
Canopy density C4	0.035	0.100	0.067
Angular scale C5	0.014	0.028	0.021
The size ratio C6	0.012	0.034	0.023
Advantage high C7	0.030	0.074	0.052
The storage is C8	0.060	0.077	0.068
Shrub and grass biomass C9	0.034	0.034	0.034
Natural Renewal C10	0.255	0.319	0.287
Forest fire risk class C11	0.010	0.006	0.008
Infestation degree of disease, insect and mouse C1	0.099	0.045	0.072
Human interference degree C13	0.087	0.024	0.056
Snow pressure C14	0.205	0.012	0.108
Humus thickness C15	0.064	0.104	0.084
Soil moisture content C16	0.024	0.012	0.018
Soil organic matter C17	0.004	0.023	0.013

3.3 Health evaluation model

In this paper, the comprehensive index evaluation method was selected to evaluate the forest health in the eastern Qilian Mountains. The model is as follows:

$$H = \sum_{i=1}^{n} \sum_{j=1}^{m} W_j x_{ij} \qquad (3\text{-}5)$$

Where, H is the forest health index, Wj is the weight of the JTH evaluation index, xij is the standardized value of the JTH evaluation index of the i th sample plot.

3.4 Classification of health evaluation levels

After calculating the health index of each standard plot according to the comprehensive index method, the health index was classified. Based on the reference of a large number of forest health classification [25-28], this study selected the currently widely used isometric classification criteria, the specific classification criteria are shown in Table 4:

Table4 Classification of forest health in the eastern Qilian Mountains

health level	**ill health**	**sub-health**	**health**	**Good health**	**High quality and health**
health index	[0,0.20）	[0.20,0.40）	[0.40,0.60）	[0.60,0.80）	[0.80,1.00]

4. Analysis of forest health assessment results in eastern Qilian Mountains

4.1 The health index of 133 plots was investigated

The health index and health grade of the sample plots are shown in Table 7. It can be seen from Table 5 that the highest health index of the sample plots in the eastern Qilian Mountains is the mixed forest of spruce and birch, which is in good health condition. The lowest health index was found in Menyuan irrigation plots, which were in sub-health status.

Table 5 Forest health index and health grade of plots in eastern Qilian Mountains

Plot number	stand type	age of stand	altitudem	ASPECT	slope gradient	health index	health level
datong countyY1	Pure larch forest	28	2861	E67°	37	0.46	health
datong countyY2	Pure larch forest	28	2838	E62°	32	0.34	sub-health
datong countyY1S	Pure larch forest	27	2767	E80°	25	0.50	health
Y3+4	Pure birch forest	45	2900	N20°	24	0.63	Good health
Y5	Spruce and birch mixed forest	48	2930	NE50°	24	0.76	Good health
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
Y6	Spruce and birch mixed forest	50	2940	NE50°	23	0.57	Good health
3s	shrub and herbaceous plant	0	2937	NW330°	12	0.19	ill health
Menyuan county16s	Spruce and birch mixed forest	12	2899	N10°	20	0.33	sub-health
Menyuan county17s	Spruce and birch mixed forest	12	2870	NW330°	18	0.35	sub-health
Menyuan county18s	shrub and herbaceous plant	0	2969	WN335°	10	0.26	sub-health
Menyuan county19s	shrub and herbaceous plant	0	2947	WS210°	20	0.23	sub-health

The results showed that 67.67% of the forest plots in the eastern part of the Qilian Mountains were in sub-health state, and the average age of the plots in health grade and sub-health grade was between 20 and 30, followed by 29.32% of the plots in health grade and the average age of the plots was between 49 and 61.

5. Spatial distribution of forest health in the eastern Qilian Mountains

In this study, the natural neighborhood method was adopted to carry out the interpolation analysis of forest health status in the eastern Qilian Mountains, and the natural neighborhood interpolation method in ArcGIS was used to analyze the forest health analysis results in the eastern Qilian Mountains, as shown in Figure 2.

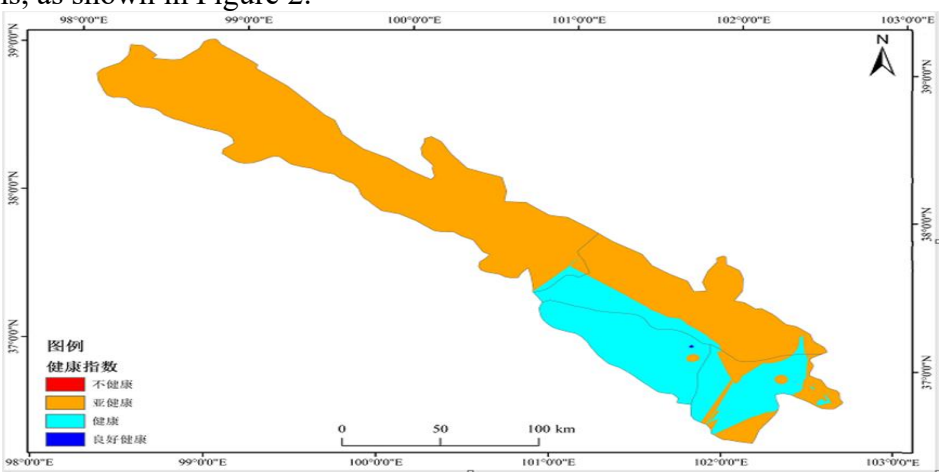

FIG. 2 Spatial distribution map of forest health in the eastern Qilian Mountains drawn by natural neighborhood method in ArcGIS

The figure shows that the forest health index of each forest land in the eastern part of the Qilian Mountains is higher than that in the western part of the Qilian Mountains.

According to the spatial distribution map of forest land with different health levels by natural neighborhood method, the forest health status of the eastern Qilian Mountains was mostly healthy and subhealthy. In the eastern mountain area of Qilian Mountains, the forest area of healthy forest land accounted for 26.26% of the total forest area, the area of sub-healthy forest land accounted for 73.72% of the total forest area, and the area of good healthy forest land accounted for 015% of the total forest area. From the above results, it can be seen that the forest health types in the eastern mountain area of Qilian Mountains were mainly sub-health and health grade. The two health types accounted for 99.98% of the total forest land area, and the health type accounted for the largest proportion was sub-health, followed by health.

6. Causes of low forest health in eastern Qilian Mountains

The forest structure, forest community productivity and forest soil quality are the main factors affecting the forest health status in the eastern Qilian Mountains. The natural regeneration is 0.319, which has the largest weight value. If the weight value is not taken into account, the average scores of 17 indicators are calculated. Observe the scores of indicators, judge the low scores of forest health indicators, and determine the impact on forest health status. The calculated results are shown in Figure 3

Figure 3 Average score of each index

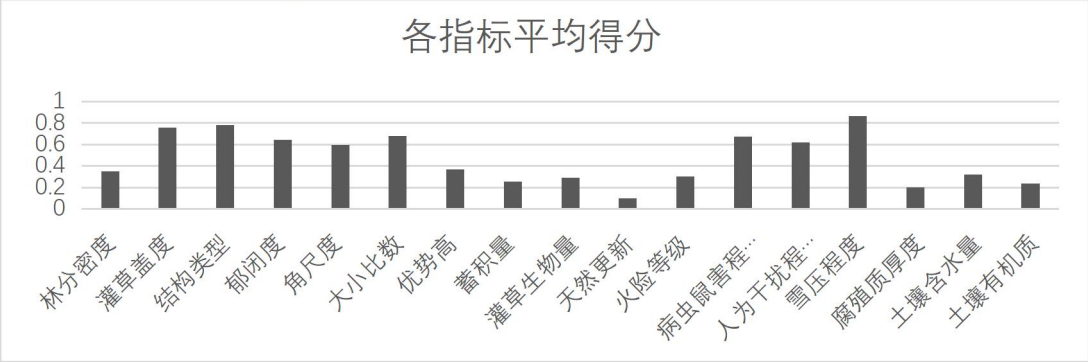

FIG. 3 shows the average data before each index is weighted. According to the statistical results, the indexes with average scores lower than 0.5 include stand density, dominance, stock, shrub biomass and soil organic matter, etc. Although there are health evaluation indexes with high scores such as shrub coverage and structure type in the eastern Qilian Mountains, However, many low scores were the main reason for the low total score of forest health in the eastern Qilian Mountains. The average score of forest health index in the eastern Qilian Mountains was low, which resulted in poor forest health status.

The scores of each evaluation index of unhealthy forest and good healthy foresare compared, and the comparison results are shown in Figure 3.

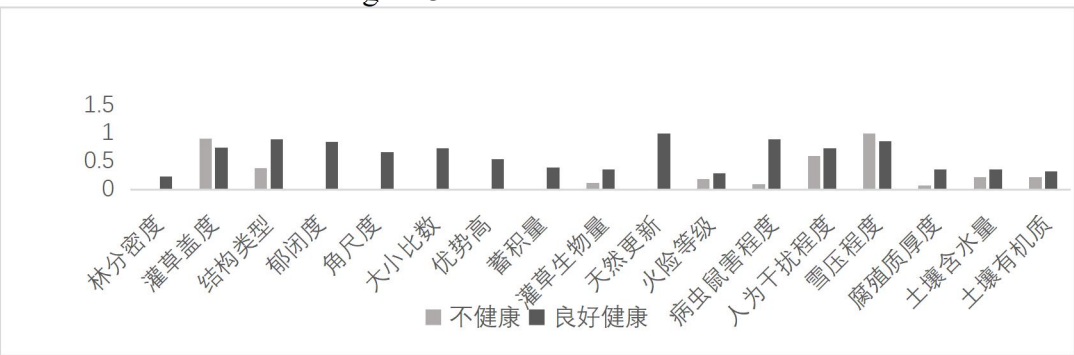

Figure 3 Comparison of average scores of unhealthy forest and good healthy forest

As can be seen from the comparison of the average scores of indicators of unhealthy forest and healthy forest in FIG.4, among the 17 indicators selected for evaluation, the scores of indicators of healthy forest are all higher than those of unhealthy forest except for the indicators of shrub cover

and snow pressure degree, especially the index of natural regeneration and canopy density. There is not only a large gap between these two indicators. And natural renewal has the highest weight value.

7. Optimization measures and suggestions for forest health status in eastern Qilian Mountains

Some measures on forest health management in eastern Qilian Mountains are put forward.Scientific and reasonable forest health operation and management should be paid enough attention. In the process of planning and decision-making, it is necessary to combine the resource characteristics of forest land, proceed from the actual situation, and adopt the principles of reasonable and orderly, overall planning, comprehensive management and classified operation and management.

In this study, natural regeneration accounted for the largest weight among the evaluation indexes, and the importance of forest regeneration to forest health in the eastern part of the Qilian Mountains can be seen. The natural regeneration status affects the growth succession of forest ecosystem. The more sapling seedlings there are, the higher the natural regeneration status of stand will be and the stronger the vitality will be. Therefore, the regeneration of forest vegetation will be strengthened, especially that of adaptive seedlings. The rationality degree of reasonable selection and renewal of seedling community structure determines whether there is fierce competition for resources among communities. In terms of age structure, there are young, middle and mature forest configurations, forming a multilayer structure [29]. Emphasis should be placed on promoting awareness of biodiversity among the general public.

In the process of forest growth and production, strict supervision and management must be carried out in the investigation and control of forest diseases, insects and rodents in the links of breeding tree species, afforestation and processing, so as to ensure the prevention and control system of forest diseases, insects and rodents, ensure the normal and healthy growth of the forest and effectively exert the forest benefits.

Formulate forest management plan, reasonably adjust forest cutting period, cutting quantity and cutting area through investigation of the actual situation of forest resources, combined with forest growth and subsequent replenishment measures, and ensure the balance between supply and demand to achieve sustainable utilization of forest resources [30].

8. Conclusion of this Paper

In this paper, the forest resources in the eastern Qilian Mountains of Qinghai Province are taken as the research object. Through sampling and field investigation of the typical forest land in the eastern Qilian Mountains, the corresponding forest evaluation index system is established, and the weight of each index is established by combining the analytic Hierarchy process (AHP) and entropy weight method. The final weight value of each index was calculated by the comprehensive weighting method, and the health index of the sample plot was determined by the comprehensive index evaluation method, so as to evaluate the health of the forest resources in the eastern Qilian Mountains.

Comprehensive weighting can be obtained as follows: Natural regeneration (0.287) > snow pressure degree (0.108) > humus thickness (0.084) > pest and rodent damage degree (0.072) > stock amount (0.068) > canopy density (0.067) > human disturbance degree (0.056) > dominant height (0.052) > stand density (0.051) > shrub biomass (0.034) > size ratio (0.023) > Angle Scale (0.021) > soil moisture content (0.018) > shrub and grass coverage (0.014) > soil organic matter (0.013) > community structure type (0.013) > forest fire risk level (0.008). Natural regeneration, snow pressure and pests were the main factors affecting forest health in the eastern Qilian Mountains.The

forest health level of 133 forest plots in the eastern part of the Qilian Mountains was subhealth. The area of subhealthy forest land accounted for a higher proportion of the study area.

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