

## Research on health assessment of main forest vegetation in Kuankuoshui nature reserve

C.W. Zhou<sup>1,2</sup>, L.B. Yan<sup>1,2</sup>, L.F. Yu<sup>1,2,\*</sup>, C.H. Zhong<sup>1</sup>, G.P. Chen<sup>3</sup>, C. Zhou<sup>1</sup>, F.J. Pi<sup>1</sup>

<sup>1</sup> Life Science College of Guizhou University, Guiyang, Guizhou, China

<sup>2</sup> Collaborative Innovation Center for Mountain Ecology & Agro-Bioengineering (CICEAB), College of Life Sciences and Institute of Agro-Bioengineering, Guizhou University, Guiyang, Guizhou, China

<sup>3</sup> Kuankuoshui National Nature Reserve Authority, Suiyang, Zunyi, Guizhou, China

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The main forest vegetation health evaluation studies in nature reserves provide scientific basis for their operation and management and are of significance for the sustainable development of forest vegetation in nature reserves and the further improvement of the nature reserves construction. This study of the Kuankuoshui national nature reserve of Suiyang county as the research object, combined with Kuankuoshui nature reserve forest resources "second subcompartment survey" in 2031 subcompartments samples and 80 000 data, applying sensitivity analysis, etc. to screen indicators, adopting an analytical hierarchy process to determine the weight of each index, set up the main forest vegetation health evaluation model of the broad water nature reserve. To assess the broad water nature reserve, evaluation analysis of the main forest vegetation health was performed. The main results were as follows: The nature reserve is in a relatively healthy grade as a whole, the forest subcompartments evaluated as unhealthy are composed by  $\geq 25^\circ$  slope farmland, shrub wood, unformed man-made forest, barren hills and wasteland suited for forestry.

Keywords: Forest health assessment, Small subcompartment, Nature reserve, Kuankuoshui of Guizhou Province

### INTRODUCTION

The forest vegetation ecosystem is a natural ecological system with the largest area [1], the most complex composition structure, the richest biological resources and relatively perfect functions on the terrestrial ecosystem [2]. The forest vegetation plays a significant role in protecting the diversity of species and avoiding ecosystem unbalance [3].

The forest vegetation resources in China are relatively tense, with a forest vegetation coverage rate and average holding volume for the forest vegetation resources lower than the world's average level [4]. However, with the rocketing development of economy and the improvement in people's living standards, under various pressures, the forest vegetation is damaged in large quantity, destroying forest resources and greatly damaging the diversity of species and forest vegetation. Therefore, the research on the forest vegetation health evaluation plays significant a role in improving the ecological environment and protecting the diversity of species. Guo *et al.* [5] in their research on the health status of the typical natural secondary forest ecosystem in the Tushi mountainous area in Northern China, employed the Comprehensive value method for the evaluation indicators to calculate the specific values

for each indicator at subcompartment level, categorizing the health degree of the forest vegetation into 5 grades. Tan [6] in his research on health evaluation of the complex network-based forest vegetation, also categorized the health degree of the forest vegetation into 5 grades by calculating the specific health indices for each landscape patch of the subcompartment network in the treatment of the subcompartment network with even distribution of areas. Wang, in the research on the health evaluation and health operation technology of the man-made forest in Hebei Mulan Paddock [7], established a hierarchical analysis structure model to categorize the health status of the forest vegetation into 4 grades as high-quality, healthy, sub-healthy and unhealthy with the principles of equivalence and the nearest rounding. Liu *et al.*, in the research on the establishment of a health evaluation system for the man-made locust forest, established an evaluation system model for the man-made locust forest with the combination of the cluster analysis method and hierarchical analysis method, categorizing the health status of the locust forests in different ages into 3 grades as healthy forest, sub-healthy forest and unhealthy forest by calculating the health evaluation indices for different sample fields [8].

Nowadays there is a diversity of studies [9,10], systems and methods for health evaluation of forests. Having referred to the relevant literature, on the basis of the theoretical studies made by a number of experts and scholars, this paper tried to explore the research methods applicable to the vegetation health

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To whom all correspondence should be sent:  
E-mail: gdyulifei@163.com

evaluation for the main forest in the Kuankuoshui nature reserve. The research theoretical system for health evaluation of forests was developed and enriched.

There is a significant difference between this study and the studies made by the experts and scholars, which is well explained by the difference of evaluation targets. Their target is of forest type, while this paper deals with a nature reserve, a virgin forest reserve with major trees of forest arbors, which is divided into three functional areas as core area, buffer area and experimental area. The vegetation here is more diversified and more complex.

## EXPERIMENTAL

### *General introduction of the studied area*

The Kuankuoshui nature reserve, located in the northwest part of Suiyang County of Guizhou Province, is part of the Dalou Mountains. Its altitude is between 651 and 1766 m, and the highest peak is located on the Sun Mountain with an altitude of 1766 m. Its geographical location is east longitude of 107°02'22" ~ 107°14'08" and north latitude of 28°06'24" ~ 28°19'26". It stretches 19 km from the east to the west and 25 km from the north to the south [11].

The Kuankuoshui nature reserve, with the greatest geographical environment and diversified habitat types, maintains 1,300 hectares of *cyclobalanopsis glauca* forest with a high natural disposition, the best preservation and the more representative concentration, and a variety of state first-level protected animals – the *Trachypithecus francoisi* and the bird with the most characteristics of Kuoshui named golden pheasant.

### *Data sources*

The second-type inventory data for the forest resources of Kuankuoshui nature reserve obtained in 2010 as the data source, the forest form map as the base map and GIS constructed the nature reserve forest vegetation resources database with the basic unit of subcompartment level. The database covers almost 80 indicators and recorded over 80,000 of forest vegetation resources data including cadastral information, forest land-related information, forest vegetation-related information, site environment and some other relevant information.

The second-type inventory data for the forest resources in the Kuankuoshui nature reserve can be

categorized into 2031 subcompartment fields, in which there are 636 core subcompartments, 461 buffer zones and 934 experimental zones. The nature reserve is composed of several kinds of fields as  $\geq 25^\circ$  slope farmland, unformed man-made forest land, pure forest, shrub forest, mixed forest, barren hills and wasteland suitable for forestry.

### *Evaluation index system*

The layer of principles: which reflect the behaviors and abilities of the forest vegetation in the nature reserve included the vigor, the organizational structure and recovery ability of the forest vegetation. The health indicators on the various layers of principles can be calculated with weights.

This research carried out health evaluations of the vegetation of the nature reserve by employing the comprehensive indicators evaluation method. Its HI calculation equation (1) is:

$$HI = \omega_1 V + \omega_2 O + \omega_3 R \quad (1)$$

In the equation, HI refers to the HI for the forest vegetation, V refers to the vigor evaluation index of the forest vegetation, O refers to the organizational evaluation index for the forest vegetation and R refers to the recovery evaluation index for the forest vegetation.

The relevant evaluation measure for the health evaluation indicators of the forest vegetation can be measured with specific values measured. For those whose index measure values cannot be determined or are inconvenient to measure, the Degree categorization method in the qualitative research is employed for the quantitative description studies, categorizing into three grades (with the natural endowments of 1, 3 and 5, respectively) with the standard of the influence level for the specific indices on the health of forest vegetation. Some evaluation indices cannot only be measured with specific values, but could also be determined by the grades categorization with the qualitative method based on the specific situations. For the relevant condition of the natural endowment and the specific grades categorization for the various indicators, please refer to Table 1.

## RESULTS AND DISCUSSION

Based on the health evaluation model established above for the main forest vegetation in the Kuankuoshui nature reserve, and with the employment of the data obtained, its health status results are calculated as follows:

**Table 1** Grades categorization for the health evaluation indices in the ‘Second Survey’ data

	Grade and Scores		
	1	3	5
Field type	Barren hills and wasteland suited for forestry ≥25 Slope farmland	Shrub forest Unformed man-made forest	Pure forest, mixed forest and bamboo forest
Advantageous trees	Pyracantha and shrub wood	Evergreen coniferous forest	Broad-leaved evergreen forests and mixed forest
Degree of naturalness	Forest type which almost maintains the primitive status with little man-made influences	Forest type with a certain disturbance by human. The top tree types can be obviously seen or expected	The forest type with a significant disturbance by human or the zonal forest type which has been almost destroyed. In the late period of retrograde succession
Slope (°)	Slope ≥36	Slope 16~35	Slope 0~16
Altitude (M)	>130	1000~1300	<1000
DBH (cm)	<10	>65 or [10, 20)	[20, 65]
Type of soil	Cultivated soil		Yellow soil, red-yellow soil and yellow-brown soil Lime soil, purple soil
Age group	Young-aged forest, Over-mature forest	Almost mature forest, Mature forest	Middle-aged forest
Degree of forest disasters	Tree crown damage ≥50% Number of damaged trees ≥50%, taking the main form of the dying wood and the dead wood	Tree crown damage 20~49%, Degree of damaged trees 20~49%, a few trees have died	No disasters have happened, tree crown damage <20%
Crown density (%)	Low level 0.20~0.39	High level ≥0.70	Medium level 0.4~0.69
Depth of soil (cm)	<40	40~79	≥80
Bedrock bare rate (%)	≥70	50~69	0~49
Degree of natural renewal	III	II	I

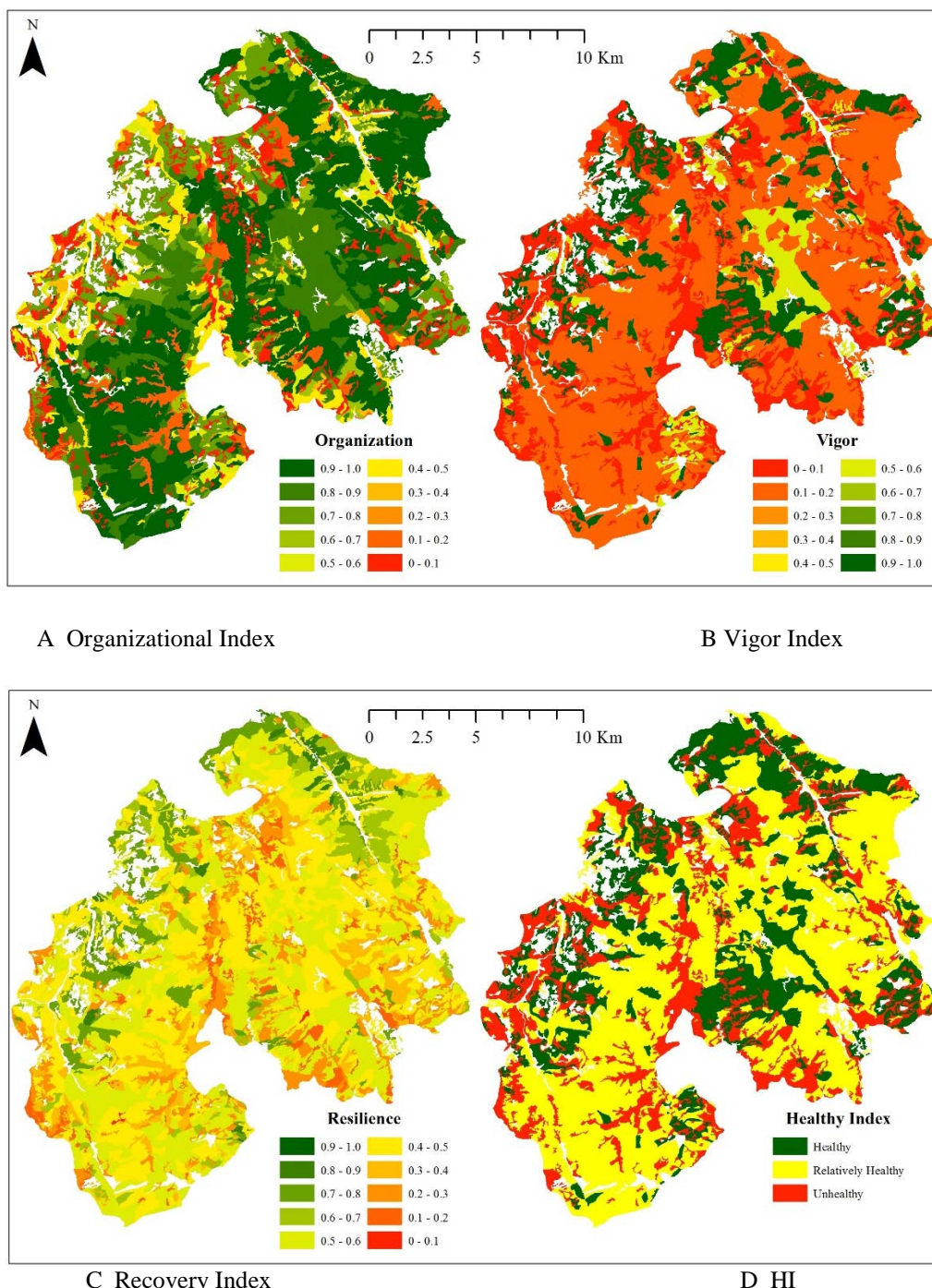
**Table 2** HI of the Kuankuoshui nature reserve

Functional zone	Organizational structure	Vigor	Recovery ability	HI
Core zone	0.728	0.318	0.482	0.509
Buffer zone	0.612	0.279	0.461	0.451
Functional zone	0.623	0.301	0.490	0.472
Total	0.654	0.302	0.481	0.479

It can be seen from Table 2 that its HI is 0.479, which falls between 0.319 and 0.634. Combined with Table 3, it is of relatively healthy grade. That means, main forest vegetation in the Kuankuoshui nature reserve is in relatively healthy status in general. In the meantime, the experimental zone, the buffer zone and the core zone are in a relatively healthy grade. The HI status for each functional zone is: core zone (I=0.510 > experimental zone (HI=0.471) > buffer zone (HI=0.451). All sub-indices for the core zone, the buffer zone and the experimental zone are: organizational index > recovery index > vigor index (Fig. 1.).

Looking from the entire nature zone, there are 447 subcompartments in the main forest vegetation

in the Kuankuoshui nature reserve that are healthy in general, taking 47.12% of the total subcompartment number. With an area of 5,766 hectares, they take 24% of the total area of the nature reserve. 957 subcompartments are in a relatively healthy status, taking 47% of the total subcompartment number. With an area of 12,736 hectares, they take 23% of the total area of the nature reserve. Looking in the different functional zones for healthy subcompartments, there are 147 blocks in the core zone, 103 blocks in the buffer zone and 197 in the experimental zone. As for the quantitative proportion, the core zone takes the largest part (23.1%), followed by the buffer zone (22.3%), and the experimental zone (21.1%), with areas of 2,101.46 hectares, 1,491.81 hectares and 2,172.61



**Fig. 1.** Health status evaluation for the forest vegetation subcompartment level in the nature reserve (A-D)

hectares, respectively, taking 36.45%, 25.87% and 37.68% of the total area of the healthy subcompartment, respectively.

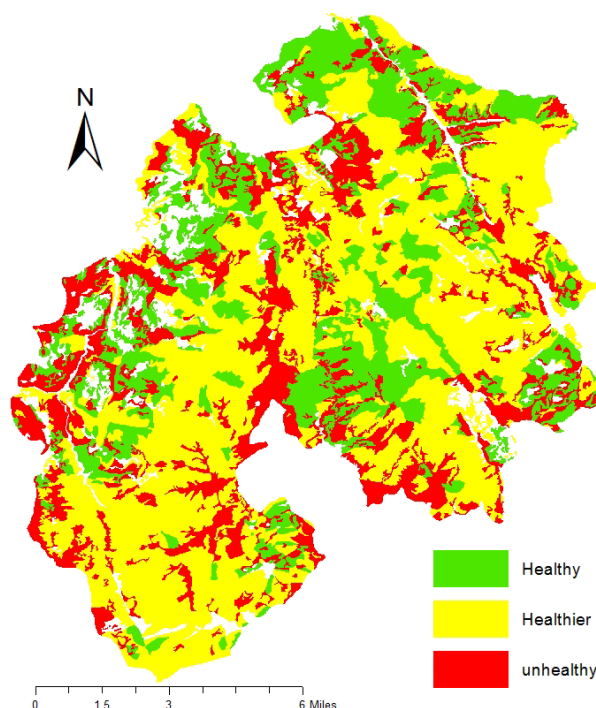
There are 342 blocks of relatively healthy subcompartments in the core zone, 183 blocks in the buffer zone and 432 in the experimental zone, with areas of 5327.26 hectares, 2482.71 hectares, 4925.83 hectares and 12735.8 hectares respectively, taking

41.83%, 19.49% and 38.68% of the total area of the relatively healthy subcompartments, respectively.

There are 147 unhealthy subcompartments in the core zone, 175 in the buffer zone and 3.5 in the experimental zone, with areas of 1,325.46 hectares, 1,623.51 hectares and 2,595.46 hectares respectively, taking 23.91%, 29.28% and 46.81% of the total area of the unhealthy subcompartments, respectively (Table 3, Figure 2).

**Table 3.** The general health condition evaluation for the Kuankuoshui nature reserve

	Healthy	Relatively healthy	Unhealthy	Total
Number of subcompartments	447 (22.01%)	957 (47.12%)	627 (30.87%)	2031
Area of subcompartments (hectares)	57656 (23.98%)	12736 (52.96%)	5544 (23.06%)	24046



**Fig.2.** Distribution map of Forest health in Kuankuoshui nature reserve

The field types in the forest vegetation of the Kuankuoshui nature reserve that fall into the relatively healthy and healthy categories are mixed forest, taking 80.3% and 56.8%, respectively.

The unhealthy field types include  $\geq 25^\circ$  slope farmland (36.7%), unformed man-made forest (25.0%), barren hills and wasteland suited for forestry (19.5%) and shrub wood (18.8%). But there are in fact infant trees in the unformed man-made forest which could reach a healthy grade with a certain time of growth. Besides, according to the regulations of the state, the shrub wood field type is already stable on the mountain top and the cliffs. Therefore, these two field types should not be unhealthy factors in the health evaluation for the Kuankuoshui forest vegetation.

Considering the different health status of the forest vegetation of the different field types, it follows that: the mixed forest has the most significant contributions to the health of forest with a proportion of 72.79%. The  $\geq 25^\circ$  slope, with a proportion of 38.10%, and the barren hills and wasteland suited for forestry, with a proportion of 21.77%, are the two major unhealthy field types affecting the health of the forest in the core zone. Therefore, converting farmland to forest and

planting trees are the major measures to recover the vegetation health of the forest in the core zone.

#### CONCLUSIONS

1. Carrying out calculations for the 2,031 subcompartments data in the second subcompartment survey for the forest resources in the Kuankuoshui nature reserve based on the forest vegetation health evaluation model it is found that the forest vegetation HI is 0.479. The nature reserve is in a relatively healthy grade as a whole, among which the core zone (HI=0.510) > experimental zone (HI=0.471) > buffer zone (HI=0.451).

2. As for the subcompartment level, there are 1,404 subcompartments above the relatively healthy level, taking 60.1% of the total subcompartments, among which there are 489 in the core zone, 629 in the experimental zone and 286 in the buffer zone, and the proportions taken in the various functional zones are 76.9%, 62.0% and 67.3% respectively. In the healthy subcompartments proportion, the core zone takes the largest proportion (23.1%), followed by the buffer zone (22.3%), and the experimental zone (21.1%).

3. The forest subcompartments evaluated as unhealthy are composed of  $\geq 25^\circ$  slope farmland,

shrub wood, unformed man-made forest and barren hills and wasteland suited for forestry (the total of these subcompartments takes above 90% of the total amount). But there are in fact the infant trees in the unformed man-made forest which could reach a healthy grade with a certain time of growth. Besides, according to the regulations of the state, the shrub wood field type is already stable on the mountain top and the cliffs. Therefore, these two field types should not be unhealthy factors in the health evaluation of the Kuankuoshui forest vegetation.

4. As for the major factors affecting the health status of the various functional zones, it is the  $\geq 25^\circ$  slope farmland (38.10%) for the core zone, the  $\geq 25^\circ$  slope farmland (31.43%) for the buffer zone, and the  $\geq 25^\circ$  slope farmland (39.02%) and the barren hills and wasteland suited for forestry (19.02%) for the experimental zone.

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