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Quality Assessment and Rehabilitation of Mountain Forest in the Chongli Winter Olympic Games Area, China

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Abstract: Spurred by the degraded forest in the 2022 Chongli Winter Olympic Games area, the Chinese government initiated a national program for mountain forest rehabilitation. We developed a method to assess the quality of mountain forests using an index system composed of stand structure, site conditions, and landscape aesthetics at three criteria levels. The method involves index weights determined by the analytical hierarchy process (AHP) and entropy method. The results show that landscape aesthetics was the most important measure for the criterion layer. Slope aspect and naturalness were the most and second-most important indices, respectively, for the alternative layer. The quality of the mountain forest in the Chongli area was divided into four grades. The area had 7.8% with high quality, 46.7% with medium quality, 36.6% with low quality, and 8.9% with inferior quality. In total 76.6% of the damaged forest were distributed on sloping and steep sloping ground at 1700 to 2050 m altitude, and *Betula platyphylla* Sukaczev and *Larix gmelinii* var. *principis-rupprechtii* (Mayr) Pilg. were the predominating trees. The damaged forest was divided into over-dense, over-sparse, degraded, inappropriate tree species, and inferior landscape forest. For different types of damaged forest, corresponding modification measures were proposed. The methods developed in this study can be used for rehabilitation projects to improve the quality of degraded forests in mountainous temperate areas.

Keywords: 2022 Winter Olympics; Chongli district of Zhangjiakou City; forest quality; damaged forest; analytical hierarchy process; entropy method

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1. Introduction

Forests are important resources of the terrestrial ecosystems and an important ecological guarantee for human survival and development [1]. China is implementing large-scale forest protection projects involving returning farmland to natural forests [2,3]. This entails not just expanding the natural forest area but also by emphasizing forest quality and biodiversity. Forest quality reflects the function and value of the forest's ecological, social, and economic benefits [4]. It not only includes the inherent attributes of the forest, but also necessary ecosystem services for various needs of humans [5]. During the last century, excessive cultivated land expansion, grazing development, and deforestation for energy purposes have decreased the world's natural forests [6]. This is causing a loss of invaluable ecosystems and natural resources for humankind. Establishment of forest quality assessment systems are the basis for understanding the status of forest quality, which will help us to better monitor and follow up the conditions of the forest stand and to take timely measures such as adapted restoration or afforestation. The success of forest restoration is inseparable from good forest governance and management practices. For example, the forest restoration project in Sabah, Malaysia promotes the restoration of natural forests and the construction of artificial forests through measures such as reforestation and tending. The results show that the implementation of sustainable forest management not only improves wood production, but also has great significance for the protection of animals and biodiversity in the region [7]. In general, forest restoration projects improve the knowledge on the selection of tree species, planting methods, seedlings, and other professional techniques, as well as the enthusiasm of local people to participate in environmental rehabilitation [8].

After it was announced that Beijing and Zhangjiakou had successfully won the right to host the 2022 Winter Olympics, Chongli District (Zhangjiakou City) in July 2015, a lot of efforts were started to strengthen forest resource protection and large-scale development to implement greening and afforestation. It was realized that the area faced problems with low biodiversity, single tree species, uneven distribution, and low forest coverage [9,10]. Additionally, several forest areas were decaying in the region. The causes of degradation in Chongli District were identified to be multiple. The region is situated in a semi-humid area where soil layers are thin, thus, less tree species are suitable for the region. The afforestation policy and forest management policy before the 1980s meant high-density afforestation, single species, and extensive cultivation [11]. This has not improved biodiversity and has caused several areas with wide-ranging forest quality problems. To improve the conditions, it was necessary to develop a method to assess the quality of semi-arid mountain forests from a multidisciplinary viewpoint.

Damaged forests have a low function regarding ecosystem services [12]. The combination of human activities, high afforestation pressure, and environmental conditions are the main factors for generation of degraded forests [13,14]. This involves many processes such as the stagnation of forest ecosystem renewal, inability to form a stable forest structure, and low ecological functioning [15]. In general, damaged or degraded forests can be defined as being affected by man-made or natural factors, leading to stagnation, or the decreasing of forest ecosystem succession, forming canopy closure stands with low density, poor aesthetics, and irrational forest structure. In view of the complexity of the problem and the number of different processes involved in forest quality and biodiversity, objective and semi-objective techniques are necessary for assessment. Yet, no specific method has been devised for this purpose. However, the analytic hierarchy process and entropy method have been widely used in water quality evaluation, ecological environment evaluation, geological disasters susceptibility assessment, economic development evaluation, and other research fields [14–21]. Thus, we developed an assessment technique for forest quality involving these methods.

Consequently, the objective of the present study was to evaluate these techniques to assess the quality of semi- humid mountain forests. We chose to use these techniques to form a mountain forest quality assessment system and analyzed the mountain forest quality and the distribution of the damaged forest in the Chongli area. The adopted forest classification and rehabilitation measures can provide a robust management support for the implementation of local forest restauration projects.

2. Materials and Methods

2.1. Study Area

The study area was located in Taizicheng, Chongli District, Zhangjiakou City, Hebei Province (Figure 1), which was one of the core competition areas in Zhangjiakou for the 2022 Winter Olympics, between 115°24′~115°30′ E longitude and 40°52′ N~40°58′ N latitude. The forest coverage of Chongli District in 2017 was 57.9%. At present, the forest coverage has increased to 67%. The greening rate of the core competition area where the research area is located has reached 80% [22]. The area is mostly mountainous, with an altitude between 1564 and 2181 m.a.s.l, and a total area of 5340.5 ha. The area of forestland and open forestland totals 1676.4 ha. The climate is continental monsoon and, due to the geographical location and topography, the winter winds are strong. Additionally, the spring temperature rises quickly but with large fluctuations. The frost period is late with a minimum temperature of −25.8 °C. The maximum temperature is 35.7 °C with an average summer temperature of 19 °C, and an average winter temperature of −12 °C. The annual average precipitation is 488 mm, and most of it falls from June to September, which represents about 80% of the annual precipitation, making rest of the months during the year rather dry [23,24]. The soil type is mainly brown soil, with a little tidal soil and coarse bone soil. The main tree species are *Betula platyphylla* S., *Larix gmelinii* var. *principis-rupprechtii* (Mayr) Pilg., *Ulmus pumila* L., *Populus davidiana* Dode, and *Prunus sibirica* L. The shrubs are mainly *Rhamnus parvifolia* Bunge, *Rosa davurica* Pall., *Corylus mandshurica* Maxim., and *Zabelia biflora* (Turcz.) Makino.

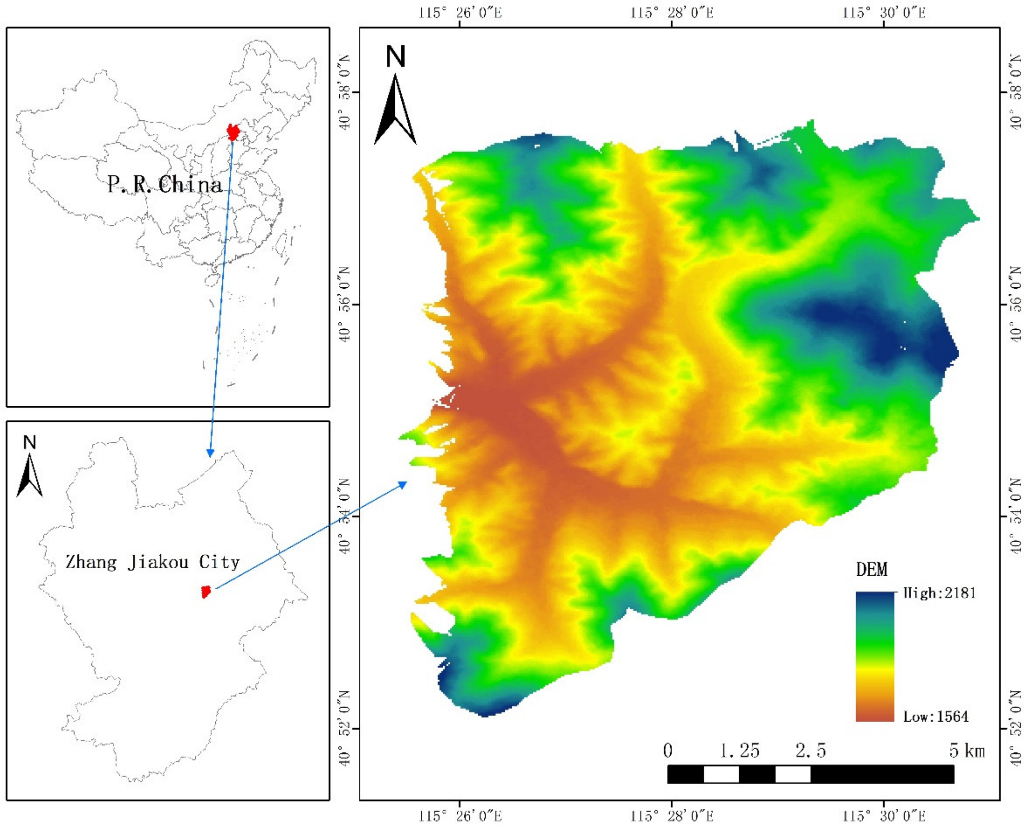

Figure 1. Location of the study area Chongli District, Zhangjiakou City in Hebei Province.

2.2. Data Source and Description

We used the surrounding and open woodland of Taizicheng in Chongli District of Zhangjiakou as an experimental study area. The subcompartment is mainly used as a managerial unit in the forest management planning inventory (FMPI) [25]. The 2017 database of forest inventory of Chongli Taizicheng region was provided by the Zhangjiakou Forestry Bureau. These data included information on 428 subcompartments on forest and open woodland in the study area, including the location, plot number, plot type, plot area, land tenure, land use type, vegetation type, elevation, soil type, slope gradient, soil thickness, slope aspect, tree species (group), dominant tree species, origin, age, age class, canopy density, mean tree height, mean diameter at breast height (mean DBH), vegetable coverage, stand density, stand volume, naturalness, and community structure.

The mountain forest quality was assessed by using three criteria, namely stand structure, site conditions, and landscape aesthetics, including canopy density, mean tree height, mean DBH, vegetation coverage, and eight other assessment indices in the alternative layer, as shown in Figure 2. Our indices were derived from the literature [12,14,15,26–30]. According to our objectives, we modified some of the indices and designed a method for a mountain forest quality assessment index system (Figure 2).

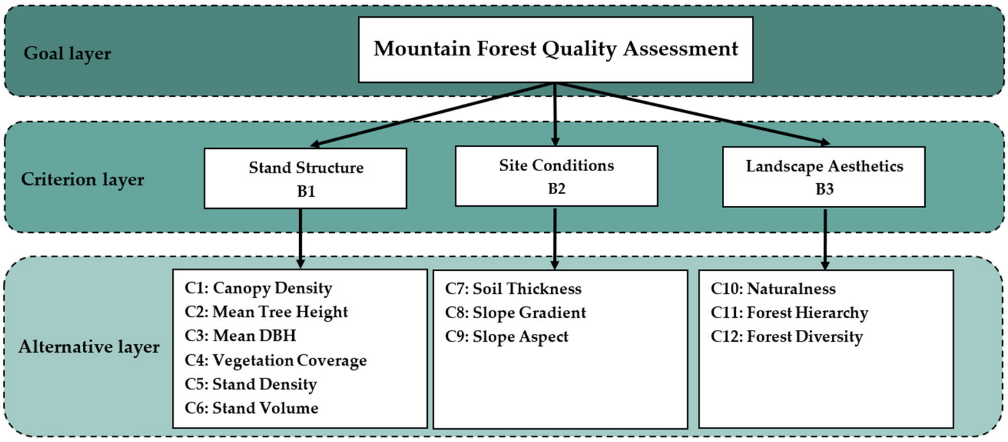

Figure 2. Methodology, including an index system of mountain forest quality assessment.

2.3. Methods

The calculation of the mountain forest quality score (goal layer) consisted of three consecutive steps. Firstly, the assessment weight index of the alternative layer was jointly determined by two methods, namely analytic hierarchy process (AHP) and Entropy Method. The combined weight of the alternative layer was determined by multiplier synthesis normalization, and the final weight of the criterion layer was obtained by adding the combined weight of the alternative layer. Secondly, index assessment scores of the alternative layer were determined. Thirdly, each assessment weight index was multiplied with the index assessment score (alternative layer) in matched pairs for every subcompartment, and then by adding them together to obtain a forest quality score (goal layer) for each subcompartment.

2.3.1. Analytic Hierarchy Process

The AHP [30–32] is a subjective weighting method. Its basic principle is to simplify complex problems through a layer-by-layer approach by dividing the objectives into clear and reasonable levels, according to internal correlation and an index hierarchy. We received 170 questionnaires from forest experts and students, who rated each indicator in the evaluation system (Figure 2) on a scale from 1–9 (Table 1) based on importance. All scores for each index were averaged to determine a matrix P for pairwise comparison of assessments for analyses of relative importance and consistency [33–35].

Table 1. Descriptive specific interpretation of relationships in the P matrix.

Relationship	Specific Interpretation
1	Indicates that the two factors have the same importance.
3	Indicates that the former is slightly more important than the latter.
5	Indicates that the former is obviously more important than the latter.
7	Indicates that the former is strongly more important than the latter.
9	Indicates that the former is extremely more important than the latter.
2, 4, 6, 8	Indicates that an intermediate value of the above adjacent judgment.
Reciprocal	If the importance ratio of factor *i* to factor *j* is *aij*, then the importance ratio of factor *j* to *i* is *aji* = 1/*aij*.

The specific steps in determining the weight by the AHP were: after constructing the matrix P, calculate the maximum eigenvalue λ_{max} and eigenvector $W = [w_1 w_{2\ldots} w_n]^T$ of matrix P, and then normalize W to determine the weight $w_i^{'}$.

2.3.2. Entropy Method

Entropy is a measure of disorder in information theory, and information is a measure of system order. Their absolute values are equal, and their sign directions are opposite. The entropy weight method determines the weight in the objective weighting method. Its essence is to determine the objective weight by using the variability of the index. Information entropy represents the measurement of uncertainty. The smaller the information entropy, the greater the weight. Similarly, the weight of each assessment index is determined by constructing the index judgment matrix.

The specific steps of the entropy method to determine the weight are the following, given that m is the assessment index and n is assessment objects, and the original matrix is [36,37]:

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \tag{1}$$

Because the measurement units of various indices are not uniform when calculating the weights, the original matrix needs to be standardized. The assessment indices are generally divided into two types, positive and negative indices. The specific standardizing formulas for different types of indices are:

positive indices:

$$r_{ij} = \frac{x_{ij} - \min_j\{x_{ij}\}}{\max_j\{x_{ij}\} - \min_j\{x_{ij}\}} \tag{2}$$

negative indices:

$$r_{ij} = \frac{\max_j\{x_{ij}\} - x_{ij}}{\max_j\{x_{ij}\} - \min_j\{x_{ij}\}} \tag{3}$$

After standardization, $R = (r_{ij})_{m\times n}$ is the standard value of the j-th assessment object for the i-th assessment index, and $r_{ij} \in [0,1]$. The entropy of the i-th assessment index is defined as:

$$H_i = -\frac{1}{\ln n}\sum_{j=1}^{n} f_{ij}\ln f_{ij} \tag{4}$$

where $i = 1, 2 \ldots\ m$, $j = 1, 2 \ldots\ n$. $f_{ij} = \frac{r_{ij}}{\sum_{j=1}^{n} r_{ij}}$. When $f_{ij} = 0$, let $f_{ij}\ln f_{ij} = 0$.

The weight of entropy of the i-th assessment index w_i'' is defined as:

$$w_i'' = \frac{1 - H_i}{n - \sum_{i=1}^{m} H_i}(i = 1, 2, \ldots m) \tag{5}$$

where $0 \le w_i'' \le 1$, satisfy the condition $\sum_{i=1}^{m} w_i'' = 1$.

2.3.3. Determination of Final Weight

To determine final weighs, we used the multiplier synthesis normalization:

$$w_i = \frac{w_i' w_i''}{\sum_{i=1}^{n} w_i' w_i''}(i = 1, 2, \ldots m) \tag{6}$$

Through the above steps, we obtained the weight of each index, the combined weight of each index, and the weight of each criterion layer in the mountain forest quality assessment based on AHP and entropy method. Finally, the combined weight of each criterion layer was determined by adding the index weights for all layers.

2.3.4. Determination of Index Assessment Scores

To follow the principle that the assessment criteria should be simple and transparent [38], two schemes were adopted for determining the score of each index. One was to adopt the original assessment index of the existing standard. The second, for the quantitative indices without assessment criteria, the sample range, sample mean, and sample standard deviation were combined with the results of near-natural forests to divide each index into grade thresholds and to assign assessment scores. The classification and assessment scores of the specific indices are shown in Table 2. It should be noted that when assigning the index assessment scores of slope aspect, it was necessary to combine the type of tree species. Slope aspect has a greater impact on plant growth. According to recent field investigations, the dominant tree species of a study area are distributed on both shady and sunny slopes, *Prunus sibirica* grows better on sunny slopes than on shady slopes, while *Betula platyphylla*, *Larix principis-rupprechtii*, *Populus davidiana,* and *Ulmus pumila* L. grow better on shady slopes.

Table 2. Division and assessment score of each index.

Index	Classification	Assessment Score
Canopy density C1	<0.3	0
	0.3–0.5	1
	0.5–0.7	2
	≥0.7	3
Mean DBH C2	<5.0	0
	5.0–10.0	1
	10.0–15.0	2
	≥15.0	3
Mean tree height C3	<3.0	0
	3.0–6.0	1
	6.0–9.0	2
	≥9.0	3
Vegetation coverage C4	<25	0
	25–50	1
	50–75	2
	≥75	3
Stand density C5	<450	0
	450–900	1
	900–1350	2
	≥1350	3
Stand volume C6	<45	0
	45–90	1
	90–135	2
	≥135	3
Soil thickness C7	<20	1
	20–45	2
	≥45	3
Slope gradient C8	<5° Flat slope	3
	5–15° Gentle slope	2
	15–25° Slope	1
	≥25° Steep slope	0
Slope aspect C9	Sunny slope (including southwest slope and south slope)	0
	Half sunny slope (including west slope and southeast slope)	1
	Half shady slope (including northwest slope and east slope)	2
	Shady slope (including north slope and northeast slope)	3

Table 2. *Cont.*

Index	Classification	Assessment Score
Naturalness C10	The natural habitat is destroyed, the original structure does no longer exist, and the landscape quality is very poor.	0
	Severely damaged, habitat degradation, poor landscape quality	1
	Minor disturbance and destruction, the habitat is basically intact, and the landscape quality is good.	2
	Rarely disturbed by human beings, landscape quality is good, the habitat and vegetation growth conditions are intact.	3
Forest hierarchy C11	Sparse forest and grassland are covered with very few tree species, with poor natural renewal ability.	0
	Single structure, some layers have multiple layer groups or no layer groups, and less capability of natural regeneration.	1
	The layer of arbor–shrub structure or arbor–grass structure or shrub–grass structure is not rich, and the natural regeneration ability is slightly better.	2
	The ground cover structure of trees, shrubs, and grass makes full use of environmental resources, and each layer has its own layer group, which is rich in layers, and a good natural renewal ability.	3
Forest diversity C12	There are few types of communities, neither abundant forests nor good ornamental value.	0
	There are a few types of communities, and the forest's appearance and ornamental value are relatively ordinary.	1
	There are different community types, such as broad-leaved or coniferous, deciduous, or evergreen, etc., with rich forests and good ornamental value.	2
	There are different community types, such as broad-leaved, coniferous, deciduous, evergreen, etc., with abundant forests and great ornamental value.	3

2.3.5. Mountain Forest Quality Assessment Model

The combined weight of each assessment index w_i and the individual index assessment y_i of the forest land sub-group was calculated, and the assessment scores of the mountain forest quality in the Chongli Winter Olympic area were obtained by:

$$S = \sum_{i=1}^{m} w_i y_i \quad (7)$$

where S is the assessment score of the evaluated object, w_i represents the weight of each assessment index, y_i represents the assessment value of a single index, and m is the number of assessment indices.

In the study area, there were 428 sub-class mountain forest quality scores, which were used in Q-Q plot analysis to determine whether the score data followed a normal distribution [39,40]. As data were normally distributed, equidistant grouping was used to determine the thresholds of different mountain forest quality levels.

2.4. Selection of Tree Species, Classification, and Rehabilitation of Damaged Forests

Site conditions are important factors affecting vegetation distribution. We tried to protect the distribution of native vegetation to both consider ecological benefits and landscape effects. This meant that we could propose suitable tree species configurations based on slope aspect, slope gradient, and elevation. The slope gradient was divided into two parts: gentle slope (<15°), and steep slope (≥25°). The elevation was divided into four parts: 1500–1700, 1700–1900, 1900–2050, and above 2050 m. The aspect was divided into sunny (including south, southwest, west, and northwest slope) and shady slopes (including north, southeast, east, and northeast slopes).

Firstly, we divided the damaged forest types into five categories: *Betula platyphylla*, *Populus davidiana*, *Ulmus pumila*, *Prunus sibirica*, and *Larix principis-rupprechtii,* according to the composition of dominant tree species in the sub-class data of the forest resource survey. Then, according to canopy density, age composition, distribution of subalpine meadow area (about 2050 m a.m.s.l), and landscape effect, the damaged forests were divided into five types (Table 3): over-dense forest, over-sparse forest, degraded forest, inappropriate tree species, and inferior landscape forest. Based on the characteristics of the different types of damaged forests, rehabilitation suggestions were put forward.

Table 3. Types and specific interpretation of damaged forests.

Code	Type of Damaged Forest	Specific Interpretation
1	Over-dense forest	Stands with a canopy density ≥0.8, mainly including young stands.
2	Over-sparse forest	Stands with canopy density <0.3, including young stands without canopy formation.
3	Degraded forest	Stands with advanced or accelerated physiological decline, resulting in tree die-back, poor growth and regeneration, reduced stability, and degradation of the forest ecosystem.
4	Inappropriate tree species	Stands that are against the principle of a suitable place and suitable tree, which refers to the selection of suitable tree species for afforestation according to the type of site conditions (altitude, slope, slope aspect, soil thickness, and other natural factors) of the afforestation, so as to unify the site conditions of the afforestation area with ecological habits of the selected tree species.
5	Inferior landscape forest	Intermediate and young forest stands with a canopy density of 0.3–0.7, single tree species, declining forest phase, few vegetation color levels, obscure seasonal phase, and poor landscape quality.

3. Results

3.1. Assessment Index Weights

The combined weight of the mountain forest quality assessment indices was calculated using multiplication synthesis normalization according to Table 4. In the alternative layer, the degree of influence of each index on the quality of mountain forests in descending order was as follows: slope aspect (19.5%) > naturalness (18.9%) > vegetation coverage (12.1%) > forest diversity (9.7%) > soil thickness (8.5%) > forest level (8.1%) > stand volume (7.6%) > canopy density (3.8%) > mean DBH (3.8%) > stand density (3.7%) > slope gradient (2.3%) > mean tree height (2.0%). For the criterion layer, landscape aesthetics had the greatest impact on the quality of mountain forests, with a contribution rate of 36.7%, followed by forest stand structures with 33.0%, and site conditions, with 30.2%. Therefore, the vegetation coverage for the forest stand structure, slope aspect for site conditions, and naturalness for the landscape aesthetics will have a great impact on the quality of mountain forests.

Table 4. Division and assessment score of each index.

Criterion Layer	Final Weight	Alternative Layer	Weight			
			AHP	Entropy Method	Combination Weight	Total Rank
Stand structure B1	0.3303	Canopy density C1	0.0607	0.0534	0.0382	8
		Mean DBH C2	0.0547	0.0592	0.0381	9
		Mean tree height C3	0.0524	0.0331	0.0204	12
		Vegetation coverage C4	0.0598	0.1713	0.1208	3
		Stand density C5	0.0584	0.0539	0.0371	10
		Stand volume C6	0.0590	0.1089	0.0756	7
Site conditions B2	0.3024	Soil thickness C7	0.1180	0.0614	0.0853	5
		Slope gradient C8	0.1070	0.0179	0.0226	11
		Slope aspect C9	0.1133	0.1457	0.1945	1
Landscape aesthetics B3	0.3673	Naturalness C10	0.1057	0.1516	0.1889	2
		Forest hierarchy C11	0.1052	0.0657	0.0814	6
		Forest diversity C12	0.1057	0.0779	0.0970	4

3.2. Quality Assessment and Distribution Characteristics of Mountain Forests

The application of QQ plots was used to test the probability distribution of the forest quality assessment scores of each sub-class. The results (Figure 3) showed that the mountain forest quality assessment scores of the study area obey the normal distribution. Therefore, we adopted normal equidistant groupings. The method divides the mountain forest quality assessment scores into four groups, namely (0.00, 0.68), (0.68, 1.23), (1.23, 1.78) and (1.78, 3.00) (Table 4). There were 26 smaller classes with a score of $Q \geq 1.78$, which were of a high quality, indicated by grade I; 180 small classes with a score $Q \geq 1.23$ and $Q < 1.78$, accounted for 46.6%, and were of average quality, indicated by grade II; 192 small classes with score $Q \geq 1.23$ and $Q < 1.78$ indicated by grade III; and 33 small classes with score $Q < 0.68$ indicated by grade IV.

Figure 4 shows the distribution of forest quality of each subcompartment. High-quality stands are concentrated to small areas. Stands with average quality are mainly distributed in the northeast and southwest of the study area. Stands with low quality are spatially scattered. Inferior quality stands are concentrated to the eastern part of the study area.

Table 5 shows that 48.1% of the subcompartments (area accounts for 54.5%) in the study area have good forest quality, while areas with poor and inferior grades account for 51.9% of the total number of subcompartments (area accounts for 45.5%). The overall quality of mountain forests is poor, which was basically in line with the visual survey. The mountain forests in the two grade areas (grade III and grade IV) are decaying, due to several problems that need rehabilitation.

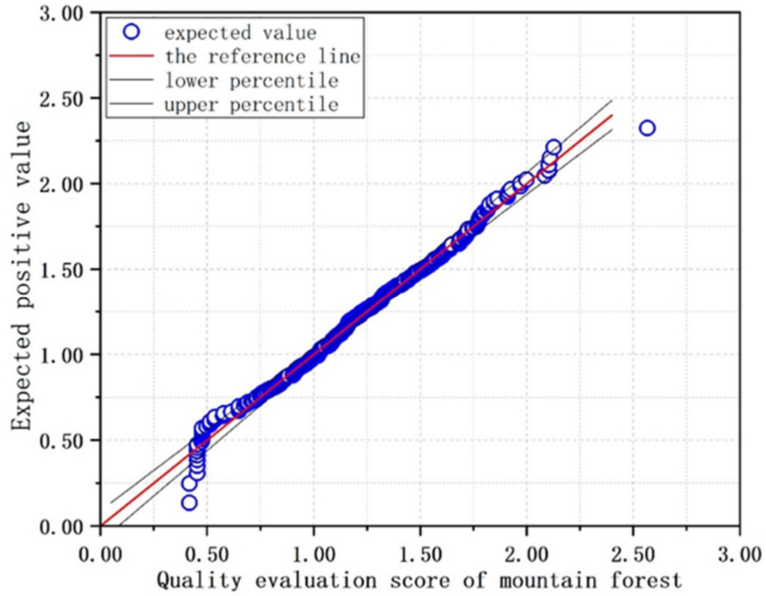

Figure 3. Normal QQ plot of mountain forest quality assessment scores.

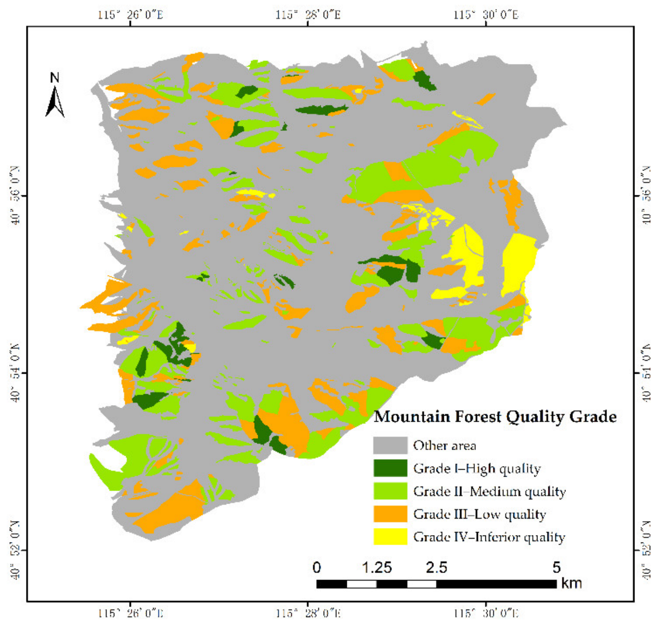

Figure 4. Distribution of mountain forest quality assessment grades.

Table 5. Summary of mountain forest quality assessment.

Assessment Grade	Range of Assessment Values Q	Number of Subcompartments	Area (ha)	Assessment Result
Grade I	Q ≥ 1.78	26	130.5	High quality
Grade II	1.23 ≤ Q < 1.78	180	782.5	Medium quality
Grade III	0.68 ≤ Q < 1.23	189	614.8	Low quality
Grade IV	Q < 0.68	33	148.7	Inferior quality

3.3. Optimize Tree Species Allocation

Native tree species and the basic ecological characteristics of damaged areas were obtained based on elevation, slope aspect, and slope gradient (Table 6). There was no damaged forest for some site types, and actual tree species configurations were designed for

19 site conditions. Trees and shrubs were not suggested for subalpine meadow areas above 2050 m. The results are presented in Table 6. Results indicate that the main types of damaged forests with an area greater than 10% were shady slope and steep slope at 1700–1900 m (28.1%), sunny slope and steep slope at 1700–1900 m (20.1%), sunny slope and steep slope at 1900–2050 m (17.3%), and shady slope and steep slope at 1900–2050 m (11.1%) altitude. The area distribution of damaged forests on sunny slopes (50.2%) was slightly larger than that on shady slopes (49.8%). With the increase in altitude, the distributed damaged forest area showed a trend of increasing first and then decreasing, that is 1700–1900 m (54.5%) > 1900–2050 m (30.2%) > above 2050 m (8%) > 1500–1700 m (7.3%). In terms of the slope, the damaged forest area distributed on gentle slopes (11.9%) was much smaller than that on slopes and steep slopes (88.1%). The main topographic features of damaged forests with an area greater than 50% to the area in each site condition were: areas above 2050 m (100%) > 1500–1700 m with a sunny gentle slope (78.3%) > 1900–2050 m with a shady gentle slope (62.0%).

On sunny gentle slopes, the suggested tree species configuration was evergreen coniferous and flowering shrub forest of *Pinus sylvestris* var. *mongolica* Litv., *Prunus davidiana* Franch., *Ulmus pumila 'Jinye'*, mixed broadleaf–conifer forest of *Populus davidiana*, *Betula platyphylla*, *Pinus sylvestris* var. *mongolica*, evergreen coniferous forest of *Larix principis-rupprechtii,* and *Pinus sylvestris* var. *mongolica*. As altitude increased, species configuration was reduced to a mix of *Betula platyphylla*, *Larix principis-rupprechtii,* and *Pinus sylvestris* var. *mongolica*.

On sunny slope and steep slopes, the suggested tree species configuration was evergreen coniferous and flowering shrubs of *Pinus sylvestris* var. *mongolica*, *Prunus sibirica*, *Ulmus pumila 'Jinye'*, *Amygdalus davidiana*, *Prunus triloba* Lindl., *Spiraea salicifolia* L., mixed broadleaf–conifer forest of *Betula platyphylla, Pinus sylvestris var. mongolica*, *Larix principis-rupprechtii,* and *Quercus mongolica* Fischer ex Turcz., as well as *Larix principis-rupprechtii,* and *Pinus sylvestris var. mongolica*. With increasing elevation and slope gradient, shrubs that were suitable (*Spiraea* and *Ostryopsis davidiana* Decne.) for growing on sunny slopes were added to the tree species configuration.

On shady gentle slopes, the suggested main species was modified with *Picea asperata*. Tree species configuration was mixed broadleaf–conifer forest of *Populus davidiana* and *Picea asperata, Betula platyphylla, Picea asperata*, *Ulmus pumila,* and *Larix princi-pis-rupprechtii,* and coniferous forest of *Larix principis-rupprechtii* with *Picea asperata*.

On the shady slope and steep slopes, the suggested tree species configuration was the shrubs of *Prunus sibirica*, *Corylus mandshurica* Maxim., *Rosa davurica* Pall., *Zabelia biflora*, *Rhamnus parvifolia*, a mixed broadleaf–conifer forest of *Betula platyphylla* and *Picea asperata*, coniferous forest of *Larixprincipis-rupprechtii,* and *Picea asperata*. Similarly, with the increase in elevation and slope gradient, shrubs such as *Corylus mandshurica* that are suitable for shady slope growth were added to the tree species configuration.

3.4. Analysis of Classification and Modification Measures

Not only is a good configuration of tree species needed, but also forest management is a necessary condition for successful afforestation. In the damaged forest region (mountain forest quality evaluation was grade III or grade IV), we divided damaged forests into 18 types depending on their initial classification. The area percentage and distribution are shown in Figure 5. The main alternative layer indices leading to damaged forest and suggested modification measures are shown in Table 7.

Table 6. Suggested tree species configurations under different site conditions.

Aspect and Slope Gradient	Elevation	AP[1]	AP[2]	Native Dominant Species	Forest Type	Configuration of Tree Species
On sunny gentle slope	1500–1700 m	0.2%	57.3%	*Populus davidiana* *Betula platyphylla* *Larix principis-rupprechtii*	Evergreen coniferous forest	*Larix principis-rupprechtii* + *Pinus sylvestris* var. *mongolica*
					Mixed broadleaf–conifer forest	*Betula platyphylla* + *Pinus sylvestris* var. *Mongolica* *Populus davidiana* + *Pinus sylvestris* var. *mongolica*
					Evergreen coniferous and flowering shrub forest	*Pinus sylvestris var. mongolica* + *Amygdalus davidiana* + *Ulmus pumila 'Jinye'*
	1700–1900 m	3.3%	41.7%	*Betula platyphylla* *Larix principis-rupprechtii*	Evergreen coniferous forest	*Larix principis-rupprechtii* + *Pinus sylvestris* var. *mongolica*
					Mixed broadleaf-conifer forest	*Betula platyphylla* + *Pinus sylvestris* var. *mongolica*
	1900–2050 m	0.4%	32.6%	*Larix principis-rupprechtii*	Evergreen coniferous forest	*Larix principis-rupprechtii* + *Pinus sylvestris* var. *mongolica*
	Above 2050 m	1.9%	100%	*Betula platyphylla* *Larix principis-rupprechtii*	Subalpine meadow	-
On sunny-slope & steep slope	1500–1700 m	1.0%	25.6%	*Larix principis-rupprechtii* *Prunus sibirica* *Betula platyphylla*	Flowering shrub forest	*Prunus sibirica*+ *Pinus sylvestris* var. *mongolica* + *Ulmus pumila 'Jinye'*
					Mixed broadleaf-conifer forest	*Betula platyphylla* + *Pinus sylvestris* var. *mongolica* *Larix principis-rupprechtii* + *Quercus mongolica*
					Deciduous broad–leaved forest	*Betula platyphylla*
					Deciduous broad–leaved and shrub forest	*Betula platyphylla* + *Spiraea* + *Ostryopsis davidiana*
					Coniferous and shrub forest	*Larix principis-rupprechtii* + *Spiraea* + *Ostryopsis davidiana*
					Shrubbery	*Prunus sibirica*+ *Ostryopsis davidiana*
					Evergreen coniferous forest	*Pinus sylvestris* var. *mongolica* + *Pinus sylvestris* var. *mongolica*
	1700–1900 m	20.1%	40.8%	*Larix principis-rupprechtii* *Betula platyphylla* *Prunus sibirica*	Flowering shrub forest	*Prunus sibirica* +*Amygdalus davidiana* + *Prunus triloba* + *Ulmus pumila 'Jinye'*
					Mixed broadleaf–conifer forest	*Betula platyphylla* + *Pinus sylvestris* var. *mongolica* *Larix principis-rupprechtii* + *Quercus mongolica*
					Evergreen coniferous forest	*Larix principis-rupprechtii* + *Pinus sylvestris* var. *mongolica*

Table 6. *Cont.*

Aspect and Slope Gradient	Elevation	AP[1]	AP[2]	Native Dominant Species	Forest Type	Configuration of Tree Species
					Deciduous broad-leaved and shrub forest	*Betula platyphylla* + *Spiraea* +*Ostryopsis davidiana*
					Coniferous and shrub forest	*Larix principis-rupprechtii* + *Spiraea* + *Ostryopsis davidiana*
	1900–2050 m	17.3%	49.2%	*Betula platyphylla* *Larix principis-rupprechtii*	Evergreen coniferous forest	*Larix principis-rupprechtii* + *Pinus sylvestris* var. *mongolica*
					Mixed broadleaf–conifer forest	*Betula platyphylla* + *Pinus sylvestris* var. *mongolica*
					Coniferous and shrub forest	*Larix principis-rupprechtii* + *Spiraea* + *Ostryopsis davidiana*
					Deciduous broad-leaved and shrub forest	*Betula platyphylla* +*Spiraea* + *Ostryopsis davidiana*
	Above 2050 m	6.0%	100%	*Larix principis-rupprechtii*	Subalpine meadow	-
On shady gentle slope	1500–1700 m	1.7%	78.3%	*Populus davidiana* *Larix principis-rupprechtii* *Betula platyphylla*	Mixed broadleaf–conifer forest	*Populus davidiana* + *Picea asperata*
					Evergreen coniferous forest	*Larix principis-rupprechtii* + *Picea asperata*
					Mixed broadleaf–conifer forest	*Betula platyphylla* + *Picea asperata*
	1700–1900 m	3.0%	33.4%	*Ulmus pumila* *Betula platyphylla*	Mixed broadleaf–conifer forest	*Ulmus pumila* + *Larix principis-rupprechtii* + *Picea asperata* *Betula platyphylla* + *Picea asperata*
	1900–2050 m	1.4%	2.3%	*Betula platyphylla*	Mixed broadleaf–conifer forest	*Betula platyphylla* + *Picea asperata*
	Above 2050 m	-	-	-	-	-
On shady-slope & steep slope	1500–1700 m	4.4%	43.9%	*Prunus sibirica* *Betula platyphylla* *Larix principis-rupprechtii*	Shrubbery	*Prunus sibirica* + *Corylus mandshurica* + *Rosa davurica* +*Zabelia biflora* +*Rhamnus parvifolia*
					Mixed broadleaf–conifer forest	*Betula platyphylla* + *Picea asperata*
					Coniferous forest	*Larix principis-rupprechtii*+ *Picea asperata*
	1700–1900 m	28.1%	41.5%	*Betula platyphylla* *Larix principis-rupprechtii* *Populus davidiana* *Prunus sibirica*	Shrubbery	*Prunus sibirica* + *Corylus mandshurica* + *Rosa davurica* + *Zabelia biflora* +*Rhamnus parvifolia*
					Coniferous forest	(*Larix principis-rupprechtii*+ *Picea asperata*)
					Deciduous broad-leaved forest	*Betula platyphylla*
					Mixed broadleaf–conifer forest	*Betula platyphylla*+ *Picea asperata*

Table 6. *Cont.*

Aspect and Slope Gradient	Elevation	AP[1]	AP[2]	Native Dominant Species	Forest Type	Configuration of Tree Species
					Deciduous broad-leaved and shrub forest	*Betula platyphylla*+ *Rosa davurica*/ +*Zabelia biflora* + *Rhamnus parvifolia*
	1900–2050 m	11.1%	62.0%	*Betula platyphylla* *Larix principis-rupprechtii*	Coniferous forest	*Larix principis-rupprechtii*+ *Picea asperata*
					Mixed broadleaf–conifer forest	*Betula platyphylla* + *Picea asperata*
					Coniferous and shrub forest	*Larix principis-rupprechtii* + *Rosa davurica* + *Corylus mandshurica*
					Shrubbery	*Rosa davurica* + *Corylus mandshurica*
	Above 2050 m	0.1%	100%	*Betula platyphylla*	Subalpine meadow	-

AP[1]: Area percentage of total damaged areas. AP[2]: Area percentage of land area of forestland and open forestland under each site condition.

(a)

(b)

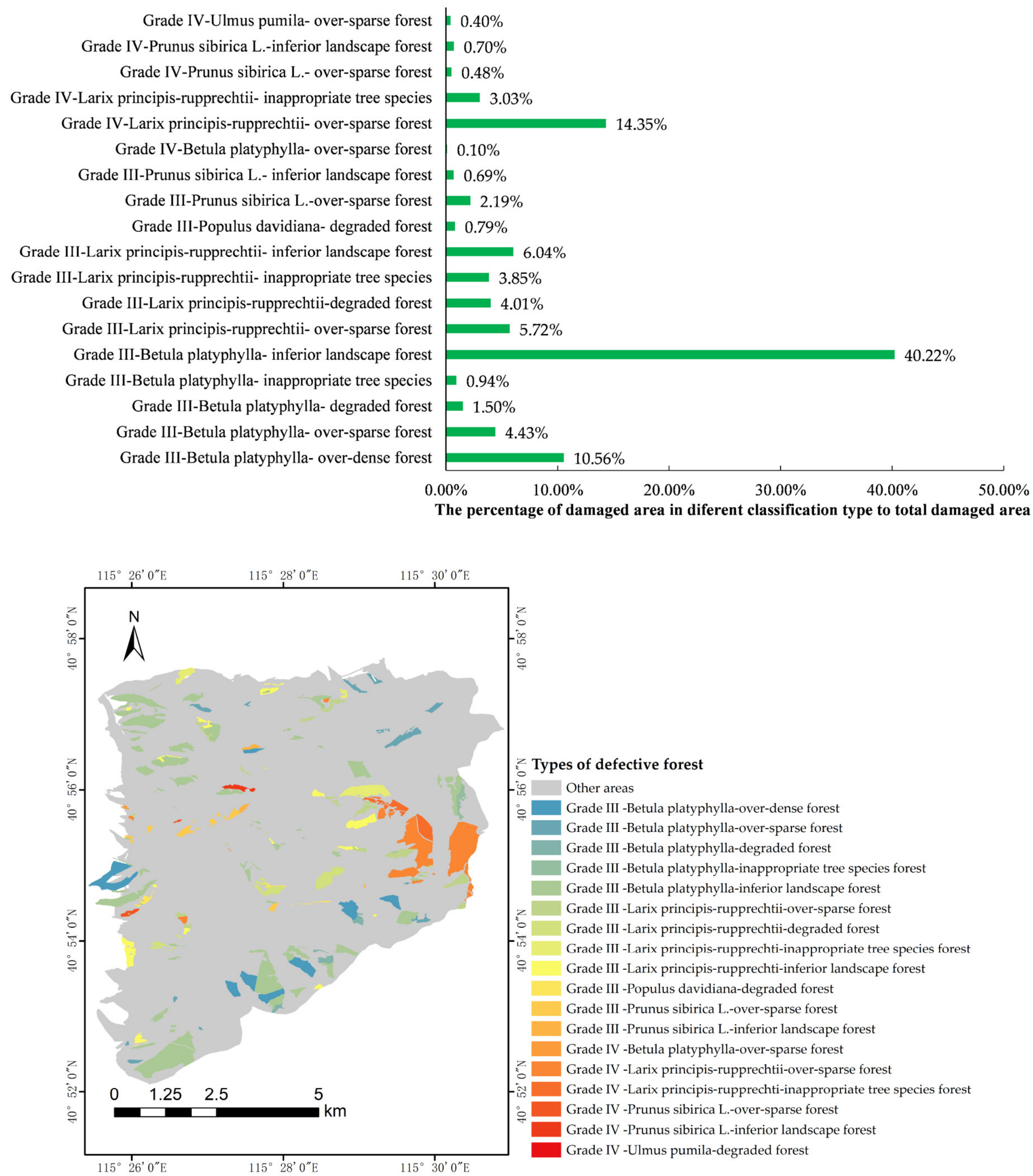

Figure 5. Area percentage and distribution of damaged forest types. (**a**) Area percentage of damaged forest classification types; (**b**) distribution of damaged forest classification types.

In the damaged forest areas, the canopy density in the over-dense forest was not less than 0.8, including natural *Betula platyphylla* forests (grade III). They accounted for 10.6% of the total area of the damaged forest and were mainly distributed in the southeast parts. The *Betula platyphylla* damaged forest was naturally sprouted or sprouting after being destroyed. The main indices affecting over-dense forest quality were vegetation coverage, stand volume, large slope gradient, unsuitable slope aspect, and less capability of forest hierarchy. We noticed that the age composition of *Betula platyphylla* damaged forests was mainly young and middle-aged trees, and the overall canopy was orderly, with a high density. However, there were many suppressed trees and stubs in the interior, with poor light penetration and crowding under the canopy, which affected the normal growth of trees. When carrying out forest restoration, we should adhere to the principle of giving priority to artificial regeneration, supplemented by the artificial promotion of natural regeneration. Thus, the over-dense forests of *Betula platyphylla* were subjected to thinning measures and a small number of gaps were formed to facilitate the natural regeneration of *Betula platyphylla* forests. Certainly, weeding is essential for young forests in the first 3 years.

Table 7. Modification measures for different types of damaged forests.

Dominant Species	Classification Type	Assessment Grade	Main Alternative Layer Indices Leading to Damaged Forest	Modification Measures
Natural forest of *Betula platyphylla*	Dense stand	Grade III	High canopy density, but low vegetation coverage and stand volume, large slope gradient, and unsuitable slope aspect, and less capability of forest hierarchy	Thinning
	Over-sparse forest	Grade III	Low canopy density, vegetation coverage, stand density and stand volume, unsuitable slope aspect, less capability of forest hierarchy, but good soil thickness	Replanting
		Grade IV	Low canopy density, vegetation coverage, stand density and stand volume, less capability of forest hierarchy and poor site conditions	Replanting, setting closed areas
	Degraded forest	Grade III	Approaching or already near-mature, mature stage, low vegetation coverage, stand volume, unsuitable slope aspect, and less capability of forest hierarchy	Selection cutting, replanting
	Inappropriate tree species	Grade III	Belonging to subalpine meadow areas, not suitable for tree species, low canopy density, vegetation coverage, unsuitable slope aspect	Reserving native trees, fertilization
	Inferior landscape forest	Grade III	Mostly pure forest, low vegetation coverage, stand volume, less capability of forest hierarchy and diversity,	Replanting, tending measures
Larix principis-rupprechtii Plantation	Over-sparse forest	Grade III	Low canopy density, vegetation coverage, less capability of forest hierarchy and unsuitable slope aspect	Replanting
		Grade IV	Low canopy density and stand volume, short tree and small mean DBH, unsuitable slope aspect, and poor forest hierarchy and diversity	Replanting, setting closed areas
	Degraded forest	Grade III	Approaching or already near-mature, mature stage, low vegetation coverage and stand volume, and less capability of forest hierarchy	Selection cutting, replanting
	Inappropriate tree species	Grade III	Belonging to subalpine meadow areas, not suitable for tree species, low canopy density, vegetation coverage, stand volume, and poor forest hierarchy	Reserving native trees, fertilization
		Grade IV	Belonging to subalpine meadow areas, not suitable for tree species, Low canopy density and stand volume, short tree and small mean DBH, and poor forest hierarchy and diversity	Fertilization, sowing grass, setting closed areas

Table 7. *Cont.*

Dominant Species	Classification Type	Assessment Grade	Main Alternative Layer Indices Leading to Damaged Forest	Modification Measures
Populus davidiana Plantation	Inferior landscape forest	Grade III	Mostly pure forest, low vegetation coverage and stand volume, and less capability of forest hierarchy and diversity	Replanting, tending measures
	Degraded forest	Grade III	Approaching or already near-mature, mature stage, low vegetation coverage and stand volume, and less capability of forest hierarchy	Selection cutting, reforestation
Natural forest of *Prunus sibirica*	Over-sparse forest	Grade III	Low canopy density and stand volume, short tree and small mean DBH, and poor forest hierarchy and diversity	Replanting
		Grade IV	Low canopy density and stand volume, short tree and small MEAN DBH, unsuitable slope aspect, and less capability of forest hierarchy and diversity	Replanting, setting closed areas
	Inferior landscape forest	Grade III	Mostly pure forest, short tree and small mean DBH, low stand volume, and poor forest hierarchy and diversity	Replanting, tending measures
		Grade IV	Mostly pure forest, short tree and small mean DBH, low stand volume, unsuitable slope aspect, and poor forest hierarchy and diversity	Replanting, setting closed areas
Natural forest of *Ulmus pumila*	Over-sparse forest	Grade IV	Low canopy density, vegetation coverage, stand density and stand volume, and unsuitable slope aspect	Replanting, setting closed areas

The canopy density in over-sparse forests was less than 0.3, mainly including naturally sprouted *Betula platyphylla* (grade III 5.7% and grade IV 14.4%) and *Larix principis-rupprechtii* plantations (grade III 4.4% and grade IV 0.1%), *Prunus sibirica* forests (grade III 2.2% and grade IV 0.6%), and *Ulmus pumila* forest (grade IV 0.40%). Grade III *Betula platyphylla* forests were mainly distributed in the northern area and the grade IV *Betula platyphylla* forests occurred along southeast bands. Grade III *Larix principis-rupprechtii* plantations were distributed in the eastern part and grade IV trees were massively distributed in the east. The grade III *Prunus sibirica* forests were in the west parts and grade IV *Prunus sibirica* forests were scattered in the west, and grade IV *Ulmus pumila* forests concentrated in the northeast corner. The main indices affecting over-sparse forest quality were poor canopy density, vegetation coverage, stand density and stand volume, unsuitable slope aspect, less capability of forest hierarchy, and diversity. There are two main reasons for the formation of over-sparse forests in the study area. One is the poor natural conditions, the slow growth of trees, and difficulty in natural regeneration. The other is human factors, such as the initiation of *Betula platyphylla*, formed by multiple man-made felling, and *Larix principis-rupprechtii* forests, formed by artificial sparse afforestation. For the natural forests of *Betula platyphylla*, *Larix principis-rupprechtii* plantations, and *Prunus sibirica* forests, *Ulmus pumila* of grade III and grade IV were replanted with evergreen conifer species (*Pinus sylvestris* var. *mongolica* or *Picea asperata*) or shrubs. Before replanting, site preparation was required, such as clearing the ground, digging out dead tree roots, and removing movable obstacles. Additionally, we kept or removed some trees and set closed areas for the *Betula platyphylla* forest and *Prunus sibirica* forests of grade IV above 2050 m.

In the study area, most of the degraded forests were planted in the 1970s–80s, mainly being *Populus davidiana* plantations (grade III 0.8%) and *Larix principis-rupprechtii* plantations (grade III 4.0%), as well as a small number in the 1950s–60s of natural *Betula platyphylla* (grade III 1.5%); grade III *Betula platyphylla* forests were scattered in the southeastern part, grade III *Larix principis-rupprechtii* concentrated in the south-central part, and *Populus davidiana* forests were scattered throughout the central and western parts. The main indices affecting degraded forest quality were low vegetation coverage, stand volume, unsuitable slope aspect, and less capability of forest hierarchy. Forest stands have gradually entered the stage of near-mature, mature, and over-mature, and the phenomenon of poor growth, decline in physiological functions, and forest stand degradation has appeared. Thus, management measures are needed in these areas. For the *Betula platyphylla* forests, *Larix principis-rupprechtii* plantations, and *Populus davidiana* plantations of grade III, we suggested artificially assisted restoration measures of selective cutting, and replanting native evergreen conifer species to create a mixed forest with better regeneration ability.

Inappropriate tree species mainly refer to the tree species that are distributed in subalpine meadow areas above 2050 m. Meadow vegetation is naturally distributed in this area, with species such as *Potentilla chinensis* Ser., *Thalictrum aquilegiifolium* var. *sibiricum* Regel & Tiling, *Geranium wilfordii* Maxim., *Aconitum sinomontanum* Nakai, *Artemisia selengensis* Turcz. ex Besser, *Cyperaceae* Juss., *Poa annua* L. et al., natural *Betula platyphylla* forests (grade III 0.9%) and *Larix principis-rupprechtii* plantations (grade III 3.9% and grade IV 3.0%) being not suitable. Grade III *Betula platyphylla* forests are distributed in the eastern part, grade III *Larix principis-rupprechtii* plantations in the northern part, and grade IV in the eastern part. The climate is cold and windy, which is not favorable to forest growth. Thus, this area is unsuitable for afforestation. The main indices affecting inappropriate tree species' quality were low vegetation coverage, stand volume, unsuitable slope aspect, and less capability of forest hierarchy. Here, we suggested native trees and fertilization to enrich the soil for the forests of grade III. As for the *Larix principis-rupprechtii* plantations of grade IV, we recommended sowing grass in closed areas.

The canopy density in the inferior landscape forest is between 0.3–0.7. The inferior landscape forest was mostly in the form of pure forest, single tree species, monotonous levels, a lack of color, and poor landscape effects, and its species composition is young and mature *Betula platyphylla* forests (grade III 40.2%), *Larix principis-rupprechtii* plantations (grade III 6.0%), and *Prunus sibirica* forests (grade III 0.7% and grade IV 0.7%). Grade III *Betula platyphylla* forests were mainly distributed in the northwest and south, grade III *Larix principis-rupprechtii* plantations were irregularly spaced, grade III *Prunus sibirica* forests are dotting the central area, and grade IV ones were distributed in the west–central part. The main indices affecting inferior landscape forest quality were short trees and small mean DBH, low vegetation coverage and stand volume, unsuitable slope aspect, and poor forest hierarchy and diversity. For natural *Betula platyphylla* forests and *Larix principis-rupprechtii* plantations, we suggested the same measure of replanting evergreen conifer species as mentioned before, to increase the green color during winter, but we also considered a younger age composition. We made full use of the native forest of *Prunus sibirica*, in order to create a better spring and summer forest landscape by replanting the ornamental shrubs of *Amygdalus davidiana*, *Ulmus pumila 'Jinye'*, and *Prunus triloba*. As mentioned before, we suggested the closing of areas of replanted forest for *Prunus sibirica* of grade IV.

4. Discussion

Forest quality assessment helps us to understand the state of forests and to rehabilitate damaged forests as a basis for management and rehabilitation measures [41]. This is of great significance for the analysis and management of regional forest quality. An efficient forest quality assessment method and appropriate modification measures are indispensable to ensure forest stability and sustainable development. In forest quality assessment, the main methods to determine the index weight are the Delphi method, analytic hierarchy process, (AHP) factor analysis, principal component analysis, cluster analysis, etc. [39,42–46]. The Delphi method and AHP contain strong subjectivity, and the evaluation results fluctuate greatly, while factor analysis, principal component analysis, and cluster analysis rely on data to calculate the weights with strong objectivity and a small fluctuation of evaluation results. However, sometimes the result will be contrary to the meaning of the indicator itself. Therefore, to overcome the above-mentioned drawbacks, the method used in water quality evaluation, a combination of analytic hierarchy process and entropy weight method, was used in this study.

The weight results of the criterion layer showed that landscape aesthetics (0.37) was the most important criterion in the mountain forest quality assessment, secondly, stand structure (0.33), and finally, site condition (0.30). Considering that Chongli is the largest ski resort in China with high touristic value, we chose shrub trees with strong ornamental features such as *Prunus sibirica*, *Amygdalus davidiana*, and *Prunus triloba*. Previous research by Gong showed that [47] forestry experts stress far-view forest landscapes. In the forest management strategies, converting pure forest to mixed forest is a common and popular approach. Felton et al. [48] considered that mixed species stands of broad-leaved tree species and coniferous species are conducive to enhancing the aesthetic value of a stand. For example, spruce–birch mixed forest can provide a variation in forest color. Thus, we introduced evergreen tree species and seasonal change effects in our study area. The main goal of the modification of the damaged forest was to improve the low forest coverage and poor forest landscape effects, improve the level of greening, and the quality of the mountain forests. There are water conservation areas and timber forests in our study area, which are important for ecosystem services for water and soil conservation, the mitigation of soil erosion, and climate regulation. The stand structure had a great weight value, which was consistent with the natural situation of the study area, and this has a certain significance for us to realize the importance of optimizing stand structure to improve forest quality. The starting point of damaged forest rehabilitation should be to make full use of the biological characteristics of plants to resist erosion, preserve soil and water, and enhance slope stability and aesthetics in severely damaged areas [28]. In terms of site conditions, slope aspect (0.19) ranked higher in the hierarchy analysis, which might indicate that the influence of aspect, slope gradient, and other factors of tree species should be stressed during rehabilitation. Good tree species configuration and management are necessary conditions for successful afforestation [49]. In addition, forests play an important role in preventing soil erosion and landslides, and the influence of slope stability should be considered when selecting tree species [50]. Inferior quality stands were concentrated on the eastern part, which had a greater relationship with poor site conditions. The study showed that 88.1% of damaged forests were distributed on slopes and steep slopes. Due to this, we chose *Ostryopsis davidiana*, *Corylus mandshurica*, and other soil and water conservation shrub species in areas with large slopes. We selected *Larix principis-rupprechtii*, *Quercus mongolica*, and *Pinus sylvestris* var. *mongolica* that have good soil and water conservation and wind resistance function. In terms of stand structure, vegetation coverage (0.12) ranked higher in the hierarchy analysis, indicating that this factor had a great impact on forest quality [46].

Natural regeneration is a complex process [51]. Research has indicated that trees in artificial regeneration have better growth and higher vitality when compared to natural regeneration, but natural regeneration provided more choices for tree breeding selection [52]. Other researchers have argued that artificial tree planting has similar early biomass and other ecological characteristics when compared to natural regeneration, but the structural complexity of planted stands is lower [53]. The natural regeneration of forests often takes longer than artificial regeneration to meet the same goals [54]. Establishing forest restoration needs, setting clear goals, and continuously monitoring the progress of restoration efforts are key components of forest restoration projects. In our case, the main goal was to solve the problem of damaged forests in the mountainous Chongli area and to improve the overall quality of forests. Considering the timeliness of the restoration project in the Chongli

Winter Olympic Games Area, our restoration research was more inclined to artificially promote natural regeneration and artificial afforestation, which is in line with the restoration project goals and policy requirements. Some researchers have found that the difference between natural regeneration and active management is that natural regeneration occurs in areas with better habitat conditions, while active management occurs in areas with poor conditions and difficult natural regeneration [53,55]. Thus, sometimes appropriate human-assisted forest management is beneficial for natural regeneration [51]. Properly thinning is generally thought necessary to promote forest regeneration, especially in dense forests. Thinning can create suitable conditions for understory seedlings to survive and grow, and can increase diversity [56]. Thinning not only changes soil nutrient concentrations but can enhance stand stability [57,58]. Likewise, the reduction of understory weeds may favor the survival and development of tree species. For example, selective weed control can avoid weeds competing with seedlings for nutrients, especially it is often applied in tree seedling stage [59,60]. Sunny slopes tend to spread fires more easily than shady ones [61], which may be related to the higher flammability of heliophile shrubs. In comparison, larger shrubs with well-developed foliage that grow in semi-shade environments are better at preventing fire from spreading [62]. Thus, the planting and management of understory shrubs on sunny slopes are important to delay and prevent future forest fires. Meanwhile, we should avoid large-scale changes in damaged forests. We need to consider the original vegetation, follow natural succession, and be selective with cutting, thus, building a mixed and stratified forest ecological system of different ages, realizing natural regeneration, and making the stand structure gradually become more stable; this can be used to implement modification measures based on ensuring the continuity of ecosystem processes and functioning [63,64]. Peng's research in the Baotianman National Nature Reserve shows that according to the management and protection measures of different naturalness levels, for the forest in its early stage of succession, strict enclosure measures should be taken to prevent human disturbance. Yang [65] concluded that different measures should be taken to nurture stands of different ages. Zhao et al. [66] emphasized the importance of reasonable replanting and later management and maintenance in the study of *Robinia pseudoacacia* L. plantation on the Loess Plateau. In view of this, we proposed forest renewal measures such as the closure of damaged forest and the tending and management of young forests.

Unfortunately, in this study, we could not use continuous forest inventory data, but instead adopted data from 2017 for processing, to determine the distribution area of remnant forest. In general, the mountain forest assessment methodology suggested by this study can be used to evaluate and grade mountain forest quality and to determine the distribution area of damaged forest. Our restoration measures can improve the status of damaged forest areas and improve long-term conditions. Finally, as a research prospect, the same method could be used to evaluate the future mountain forest quality of the region, and the obtained results can be compared with the results of this paper.

5. Conclusions

In the evaluation of forest quality, we should consider the forest's site conditions, stand structure, and landscape aesthetics in order to apply appropriate evaluation methods. In this study, we suggested a methodology for grading the quality of mountain forests based on the analytic hierarchy process (AHP) and entropy method. For different types of damaged forests, corresponding modification measures were proposed. The main conclusion are as follows:

(1) The AHP and entropy methods improve the forest assessment and make it more objective. The weight values of the evaluation indicators in the Chongli Winter Olympic Games area show that the slope aspect, naturalness, vegetation coverage, and forest diversity are the key factors to assess forest quality. Slope aspect was a consideration in tree species configuration and improving naturalness and vegetation coverage level were important goals of the forest restoration.

(2) The distribution of damaged stands in the Chongli Winter Olympic Games area was different under different site conditions. The area of damaged stands was larger on sunny slopes than on shady ones; slopes and steep slopes (slope gradient ≥15°) occupied most of the area that was between 1700–1900 m.a.s.l.
(3) Refining the type of damaged forest region can facilitate subsequent modification measures. In our restoration measures, human intervention has weakened with the decrease in mountain forest quality.
(4) Forest diversity and aesthetics can be greatly improved by conversion from pure plantations into mixed forests and increasing tree species in aesthetic value.
(5) The mountain forest quality evaluation system proposed in this study can be applied to other mountain forests in temperate semi-humid regions.

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