Ecological evaluation of forest wellness--taking Qinyuan County of Shanxi as an example

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Abstract. From the perspective of forest wellness, it is found that on county territory ecological evaluation is the important basis of sustainable development for tourism destinations according to the relevant research of ecotourism. An evaluation index system is constructed according to the standards for forest wellness industries. Combined with entropy method and ecological carrying capacity, weighted overlay analysis method is used to evaluate the ecological suitability of forest conservation in townships. Areas with consistent or conflicting suitability and ecological buffers are clarified by comparing the evaluation of the ecological suitability of the basic environment and forest resources. The existing county spatial layout is conducive to spatial integration of related industries, protection of forest resources and pollution control. This study provides a scientific basis for the sustainable development of the forest wellness industry.

1. Introduction

Forest wellness is a kind of health care activity using of forest ecological resources to develop activities that help people regulate body functions, and promote physical and mental health[1]. For the prolific fusion model of forest wellness, it is necessary to explore the balance mechanism of forest development and protection in industrial planning [2], in order to realize the actual utility of forest health and sustainability of the industry.

Chinese forest wellness is still in the exploratory stage, so sustainable development will be an important issue in the next development stage since 2020 [3], which is related to sustainable land use[4]. Ecological evaluation, evaluating the impact of land use on the basic land attributes and ecological processes in long term, provides reference for economic and social development. Therefore, ecological evaluation is the basis of sustainable land use evaluation as well as forest wellness industry [5].

Existing researches are mostly at scenic spots or regional scale. However, due to the vast territory of China, the forest species vary greatly in different regions, so the macro policies and norms of forest wellness are poorly targeted and implemented. This study aims to discuss the methods of ecological suitability evaluation in the planning and development of forest wellness at county territory, the general scale of Chinese forest wellness industry planning and the basic unit of ecological policy formulation and implementation. Relatively, the study of sustainable development of tourism started with the concept of eco-tourism[6,7]. By reference to the elements of eco-tourism, including tourism
resources, tourism environment, tourists and tourism [8], the ecological impact assessment system of forest wellness is built on aspects of forest health and tourism resources. After adjusting the number of indexes then refining and reconstructing some indexes according to local conditions, the indexes are calculated with unit of spatial granularity of the basic data.

2. Study area
Qinyuan county is located in the northwest of Changzhi City, Shanxi Province. Dominated by mountainous landforms, the county has a total forest area of 3,111,300 acres and forest coverage rate of 56.7%, ranking first in the Shanxi Province. The forest vertical zoning is obvious. Among more than 130 species of forest trees, *Pinus tabulaeformis* is most widely spread. The county is located in a warm-temperate continental monsoon climate zone. Rich water resources jointly make the environment comfortable and suitable for forest health activities.

The main areas for eco-tourism development include forest nature reserves, forest parks and public welfare forest farms, while low-level forest management entities are often extensively managed and predatory developed. Similarly, except state-owned forest farms and forest parks, the rest of the forest area in Qinyuan county have not clarified the development mode and intensity. Hence the ecological suitability evaluation provides new ideas for the sustainable development of forest wellness in the county.

3. Materials and assessment methods

3.1. Materials
The basic data for environmental evaluation include the distribution and production statistics of industrial and mining enterprises in Qinyuan county, distribution statistics of total water resources, drinking water monitoring data, monitoring results of surface water environment quality in Qinhe River basin, automatic monitoring results of environmental air quality in 2017 and 2018, and bulletin of environmental air quality in counties (cities, districts) in 2018 and 2019. The basic data for forest resources and environmental assessment come from the forest resource statistics, as well as the forest age and stand distribution data.

3.2. Constructing of the evaluation index system
According to the environmental status and forest resources of Qinyuan county, adjustment of evaluation grading and supplement of sub-indicator system refer to the regional macro indicators and ecological needs of the landscape. The smallest unit of evaluation is landscape or township, of which the boundaries are determined by the interacting principle of landscape structure and process, mainly combining the features of vegetation and hydrology. Assignment and evaluation of each factor are carried out with quantitative method. Finally the result is synthesized in ArcGIS.

Resource condition of forest wellness in "Planning guidelines for forest based health and wellness base" (LY-T 2935-2018) and the quantitative indicators of "Quality standard of forest based health and wellness base" (LY/T 2934-2018) can reflect the suitability of land utilization [9]. Those also cover the evaluation of ecological environment conditions and recreational value, to which the ecological suitability evaluation elements of forest wellness are determined by referring.

Forest wellness ecological suitability evaluation index system of Qinyuan county (Table 1) is established according to relevant standards, documents and regulations. Environmental quality reflects the ecological environment conditions. And forest quality reflects the recreational value. The comparison of the two parts would show the ecological impact of current land use and help making preliminary judgments for planning zoning and predicting the sustainability of forest wellness in Qinyuan. The three layer of the evaluation system includes target layer, criterion layer and index layer [10]. The weight determination basis "Quality standard of forest based health and wellness base" (LY/T 2934-2018). In the criterion, layer environmental quality and forest quality is equally weighted.
The weight ratio of environmental quality indicators is 2:1:1. The weight ratio of forest quality indicators is 1:1:1.

### Table 1. Evaluation index system of ecological suitability for Qinyuan county.

| target layer     | criterion layer | indicator layer                  | grading       | suitability value | weight |
|------------------|-----------------|----------------------------------|---------------|-------------------|--------|
| environmental    | Suitability of  | water quality                     | Unsuitable    | 0                 | 1/4    |
| quality          | Suitable        | more suitable                    | 1             |                   |        |
|                  | optimum suitable| high pollution                   | 2             |                   |        |
|                  |                  | low pollution                    | 3             |                   |        |
|                  |                  | no pollution                     | 0             | 1/8               |        |
| Suitability of   | forest coverage  | below 50%                        | 0             |                   |        |
| forest wellness  | rate            | 50%-60%                          | 1             |                   |        |
|                  | 60%-90%         | 2                                |               | 1/6               |        |
|                  | above 90%       | 3                                |               |                    |        |
|                  | young forest    | 0                                |               |                    |        |
|                  | middle age forest| 1                               | 1             | 1/6               |        |
|                  | near-mature forest| 3                             |               |                    |        |
|                  | Health care function of stand | low | 0              |                   |        |
|                  |                  | middle                          | 1             |                   | 1/6    |
|                  |                  | high                            | 3             |                   |        |

3.3. Data processing and assignment of indexes

By the principle that sustainable development should be established on the basis of sustainable ecological carrying, environmental monitoring data is combined with local industrial development to estimate the ecological status of the basic environment. Water quality suitability is an important limiting factor. Considering the incomplete coverage of township data, the concept of water quality bearing ratio (formula (1)) is proposed as a basis for evaluation referring to the calculation methods of environmental carrying capacity [11] and water resource load index [12].

Although Qinyuan county is located at the source of the Qin River, it is still a water-deficient area with rich mineral [13]. However, industrial development has damaged the health of the river ecosystem to a certain extent [14]. Therefore, the water quality suitability evaluation process is as follows: preliminary evaluation is carried out with the water quality bearing ratio \( p \). \( p=0 \) means no pollution, \( 0<p\leq1 \) means not exceeding the standard, \( 1<p\leq5 \) means exceeding the standard, and \( p>5 \) seriously exceeding the standard. According to the water environment resource allocation theory [15], the preliminary evaluation results are revised based on the water quality monitoring results from 2015 to 2017. Then the final water quality suitability assessment is obtained, which was divided into 4 levels: unsuitable, suitable, relatively suitable and most suitable.

\[
p = \frac{c}{w} \quad (1)
\]

\( p \): water quality bearing ratio

\( c \): according to the degree of influence of different types of enterprises on water pollution and their production capacity, the COD production of each river basin and township is estimated, which is regarded as the COD consumption of water

\( w \): the product of surface water class II COD concentration index [16] and the total water resources of every township or water basin.

Taking ecological impact assessment as principle and combining with the environmental requirements of forest wellness, the air quality in Qinyuan county basically meets the forest wellness
standards according to air quality monitoring data in 2018. However, Qinyuan county is one of the key coal-producing counties in China, with a coal-bearing area of approximately 2040 km². As of the end of 2018, there have been 26 industrial and mining enterprises above designated size (at national scale) in Qinyuan county. Therefore, air quality assessment mainly considers the main links of coal logistics system, namely the diffusion range and impact degree of particulate matter from industrial and mining enterprises [17,18]. The ecological suitability of air quality is divided into three levels. The pollution level within 2km of industrial and mining enterprises is high, within 2km-4km of industrial and mining enterprises and within 100m on both sides of transportation roads is low. The rest of the area is regarded as air pollution-free.

The noise quality evaluation mainly considers the noise impact range of large-flow roads and industrial and mining enterprises. Summary of relative studies indicate that average noise radiation radius is about 500m. The noise ecological suitability is divided into two levels: noise-affected area and noise-free area, which shows as the buffer zone built in ArcGIS around the distribution points of industrial and mining enterprises and the main transportation roads, Provincial Highway 323 and 222.

Under the forest resource index level, the forest coverage and forest age of most tree species are generally positively correlated with the forest health effects and ecological benefits [19]. But due to the differences in form and structure of different forest stands, their health functions are quite different.

Table 2. Evaluation of forest stand healthcare function.

| Forest Stand Composition and content of plant | Air negative ion concentration | Cooling and humidification level | Carbon fixation and oxygen release level | Dust detaining level | Forest stand healthcare function grades | Forest healthcare evaluation |
|-----------------------------------------------|-------------------------------|---------------------------------|------------------------------------------|---------------------|----------------------------------------|------------------------------|
| Pinus tabuliformis                            | 2                             | 1                               | 1                                        | 0                   | 2                                      | 1.83                         | middle                      |
| Larix gmelinii                                | 2                             | 1                               | 1                                        | 0                   | 2                                      | 1.83                         | middle                      |
| Platycladus                                    | 2                             | 2                               | 0                                        | 0                   | 2                                      | 1.90                         | high                       |
| Quercus acutissima                            | 1                             | 0                               | 2                                        | 1                   | 1                                      | 1.54                         | low                        |
| Betula L.                                     | 1                             | 0                               | 2                                        | 1                   | 1                                      | 1.54                         | low                        |
| weight                                        | 0.25                          | 0.25                            | 0.18                                     | 0.17                | 0.14                                   |                              |                            |

The grading of forest coverage rate in the standard is appropriately modified based on the low forest coverage rate in Shanxi Province and combined with natural breaks grading of forest coverage rate data of every township in Qinyuan county. The forest age assessment is divided into three grades: young forest, medium forest and near-mature forest. The main stands in a certain continuous area (accounting for more than 80% area) are taken as the age grade indicator of the area. The assessment of forest stand health care function is evaluated according to relevant studies on plant health care function by comprehensive comparison method. According to the vegetation types of Qinyuan county, the health assessment of stand is graded [20-27]. Then in sas statistical software, entropy method [28] is used to calculate the weight and ranking of 5 indicators (Table 2).

4. Evaluation results and data visualization

4.1. Environmental quality
As can be seen from the water quality evaluation results (Figure 1 (a)), the west and the northeast have highest suitability, because the area covers water sources with abundant water resources and few industrial and mining enterprises. From the middle to the south is the area where the water quality is more suitable, because some tributary merging from south which alleviates the accumulation of pollutants in the water from the upstream. The north is the area where the water quality is not suitable for forest wellness for the densest distribution of industrial and mining enterprises. Comparing qualitative evaluation and quantitative data of water quality, some densely distributed areas of industrial and mining enterprises have better water quality owe to the inflow of tributaries. The
industrial and mining enterprises are mainly distributed around the provincial highway 323 and 222, with dense distribution from the north to the middle and the west, and the surrounding air quality and environmental quality are poor (Figure 1 (b)(c)).

The environmental quality evaluation (Figure 1(d)) is obtained from the decentralized superposition analysis of the three environmental factor indicators in ArcGIS. The result shows that the ecological suitability is high in the east, west and northeast corner of the county, while relatively low in the north and southwest due to the influence of industrial and mining enterprises and roads. The impact of industrial distribution on the environment is multi-dimensional. The ecological environment condition of industrial surroundings is poor. Correspondingly the ecological carrying capacity decreases, mainly in the aspect of water quality in the basin. In addition, air pollution and noise radiation will reduce the recreation value of the corresponding area.

4.2. Forest quality

As can be seen from the forest coverage evaluation results (Figure 2 (a)), the forest coverage rate of Wanghe Town on the north side is the lowest. That of the five towns connected from the west to the northeast reaches over 90%, and the rest are at the middle level.

As can be seen from the results of forest age assessment (Figure 2 (b)), there are dense near-mature forests in the west, north and south. Immature timber dominates in the east. Young forest dominates in the northernmost and the middle. The northeast and southwest corners distribute all forest age layers. The average forest age of the county is above middle age, of which the proportion is the largest. The near-mature forest scatters around the county. The young forest is mainly distributed around the regions with a large degree of development and construction. On the whole, the overall forest is mature and stable.

As can be seen from the results of forest stand health care evaluation (Figure 2 (c)), Wangtao Township, Congziyu village, Hanhong village and Lingkongshan Town locate in the Taiyue Mountain National Forest Park and Lingkong Mountain Scenic spot where there are Pinus, Betula L. and Larix gmelinii compound forests, which have the highest forest stand health care value. Pinus tabuliformis, Pinus sylvestris and Pinus armandii Franch are the most widely distributed in the county, with moderate health care effect. The areas with low forest coverage are mostly young birch forests, with low health care function and poor health care effect.
Figure 2. Suitability evaluation for forest resource and Environment.

Synthesizing the above forest coverage, forest age distribution and forest stand health evaluation, Qinyuan county’s forest resources and environmental suitability evaluation were obtained (Figure 2 (d)). *Pinus tabulaeformis* forests have the widest distribution area, the highest coverage, large proportion of near-mature forests and excellent health care effects. Wanghe town features *Picea* and *Platycladus* communities. Wangtao village features *Larix gmelinii* forests. Zhongyu village features *Quercus acutissima* and other hard broad-leaf plants. The forest coverage rate and forest stand health care evaluation show good continuity. In contrast, for the impact of mining industry, the distribution of forest age has strong spatial differentiation and edge complexity. Taking the central area as an example, where industrial and mining enterprises are densely distributed, although the coverage rate of forest is relatively high, most of the plants are young, indicating that forest quality is affected by human disturbance.

For forest environment and resource, the strip of Congziyu village, Guodao town and Hanhong village is the most suitable area. Wanghe town to the north is the most unsuitable area. The central part and Zhongyu village to the southwestern are more suitable areas. Guantan village and the southeast areas have relatively low suitability. Multiple suitability levels appear in some townships, which means further district planning should be done. The forest resources and environment in the county are generally in good condition, with outstanding characteristics, high coverage, and diverse health care functions, which are suitable for the development of forest wellness industries.

4.3. Ecological evaluation result of forest wellness

Based on the above evaluation results, the environmental and forest comprehensive evaluation results are subjected to equal weight for overlay analysis in ArcGIS. The ecological suitability evaluation grading of forest wellness in Qinyuan county (Figure 3) and the area ratio of each classification area (Table 3) are obtained.

The specific suitability analysis should be carried out according to the results of each index within the indicator layer and the criterion layer, then could the functional zoning and planning scheme be determined. In the regions with the same or opposite spatial distribution of each element, different sustainability can be obtained as follows.

1. Suitability of two indicator layer in the west and northeast are consistently higher, because of better forest resources reserves in the west and low degree of human disturbance in the northeast. Yet core areas still need to be set up in the range of good forest resources. Suitability of two indicator layer in the southern and northern are consistently low with worst sustainability. The surrounding vegetation buffer is necessary for separate isolation, so as to carry out pollution control and ecological restoration.
The central strip along the distribution of the industrial and mining enterprises has low suitability where reasonable and effective protection and construction of ecological system are needed urgently.

(2) Congziyu village in central area, Liyuan town and Lingkongshan town in the southwest are highly suitable on aspect of forest resource while unsuitable on aspect of basic environment. That indicates that the areas have healthy ecological environment basal and better forest environment. But due to human disturbance, the areas are under the risk of ecological environment destruction at present. Weak sustainability needs focus of pollution control and ecological protection.

![Figure 3. Comprehensive suitability Evaluation.](image)

**Table 3. Area of ecological suitability Distribution.**

| Ecological suitability evaluation | Unsuitable | Suitable | More suitable | Optimum Suitable | Sum |
|----------------------------------|-----------|----------|---------------|------------------|-----|
| Area ratio(%)                   | 5.04      | 47.19    | 32.17         | 15.60            | 100 |
| Area(km²)                       | 128.61    | 1205.13  | 821.71        | 398.55           | 2554|

5. **Conclusions**
The evaluation result shows that most area of the county is suitable to develop forest wellness. And the suitability gradually distributes in the county, which is helpful to make use of forest resource more efficiently. However, the layout of forest wellness industry is not simply defined by the final result. The consistency or converse between environmental and forest quality suitability in the same region also reflects the different potential to develop forest wellness, especially in the regions having nearly the same comprehensive suitability but differing in environmental and forest quality. Regions with better environment quality but worse forest quality are usually townships around mature forest are
suitable to construct tourism facility. On the contrary, regions with better forest quality but worse environment quality are usually industry regions near or within forest, which are suitable to set ecological barrier and control the pollution properly. The regions with better ecological environment conditions and recreation resources are optimum suitable for forest wellness activities, having better sustainable development potential.

The evaluation of the ecological suitability of forest wellness requires a comprehensive and accurate understanding of the character and requirements of the industry. The entropy method is used to synthesize relevant research results to evaluate the suitability of forest resources with weighted synthesis carried out. The method makes up the deficiency of the forest quality evaluation system of forest wellness for diverse forest stand in China.

Breaking through the landscape boundary of the forest protection area, this study evaluates the ecological suitability of forest wellness at county scale, makes an overall judgment on the sustainability of townships: ①Under the premise of large amounts of domestic tourists and difficulty in unifying tourism concepts, the ecological protection responsibility of planning should be strengthened. During planning stage, suitability evaluation is conducive to spatial optimization, clarifying the resource features and advantages of each district. During management stage, suitability evaluation helps to implement spatial and temporal zoning guidance with trails and paths; ②Ecological suitability evaluation is conducive to refine the ecological protection regulations in counties and to realize the grading of ecological compensation mechanisms, which would promote the implementation of specific protection or development strategies in communities or townships and the participation of local residents.

However, due to the lack of monitoring data and poor system matching, it is hard to conduct a comparative study of qualitative and quantitative evaluation of all indicators. In the future, based on the preliminary evaluation results, further environmental monitoring points should be added in the study area, and forest quality testing should be carried out in the forest reserve. Then could the prediction and assessment of the sustainable development of forest wellness be promoted.

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